THE PRODUCTION ENGINEER

THE JOURNAL OF THE INSTITUTION OF PRODUCTION ENGINEERS

D.D.M.

JUNE 1960

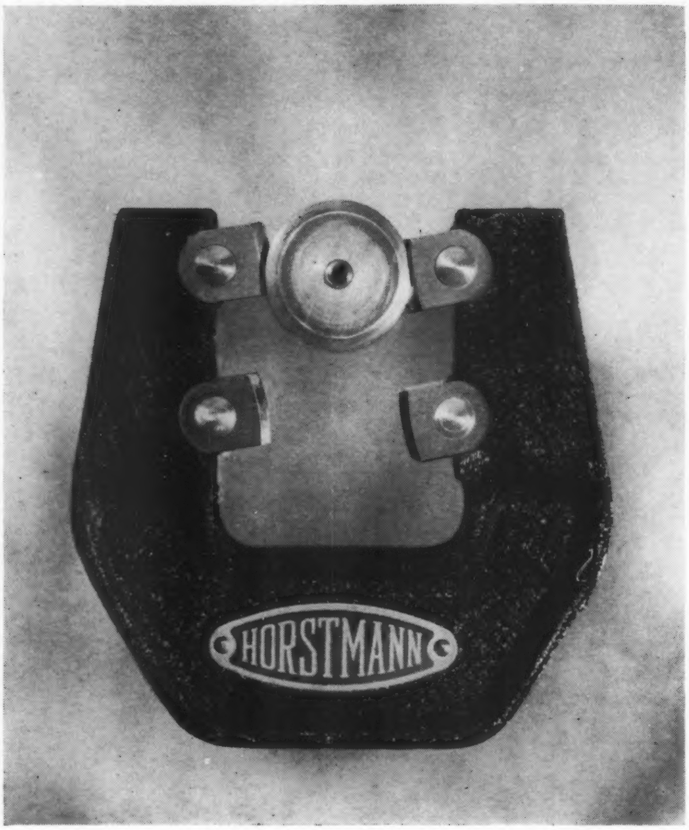
THE PRODUCTION ENGINEER

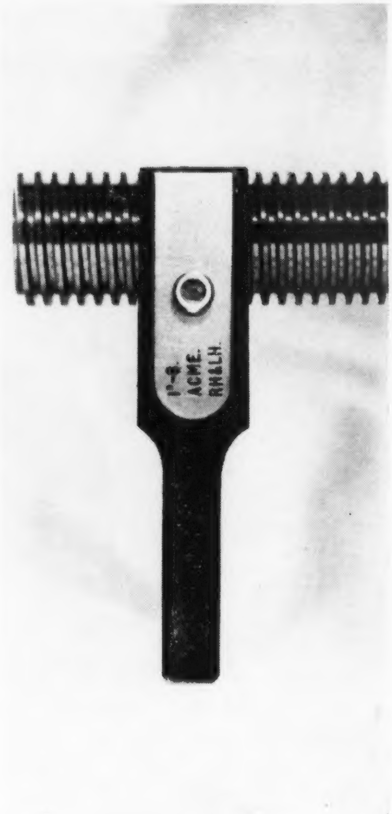
VOL. 39 - No. 6 PRICE 10/- JUNE 1960

CONTENTS

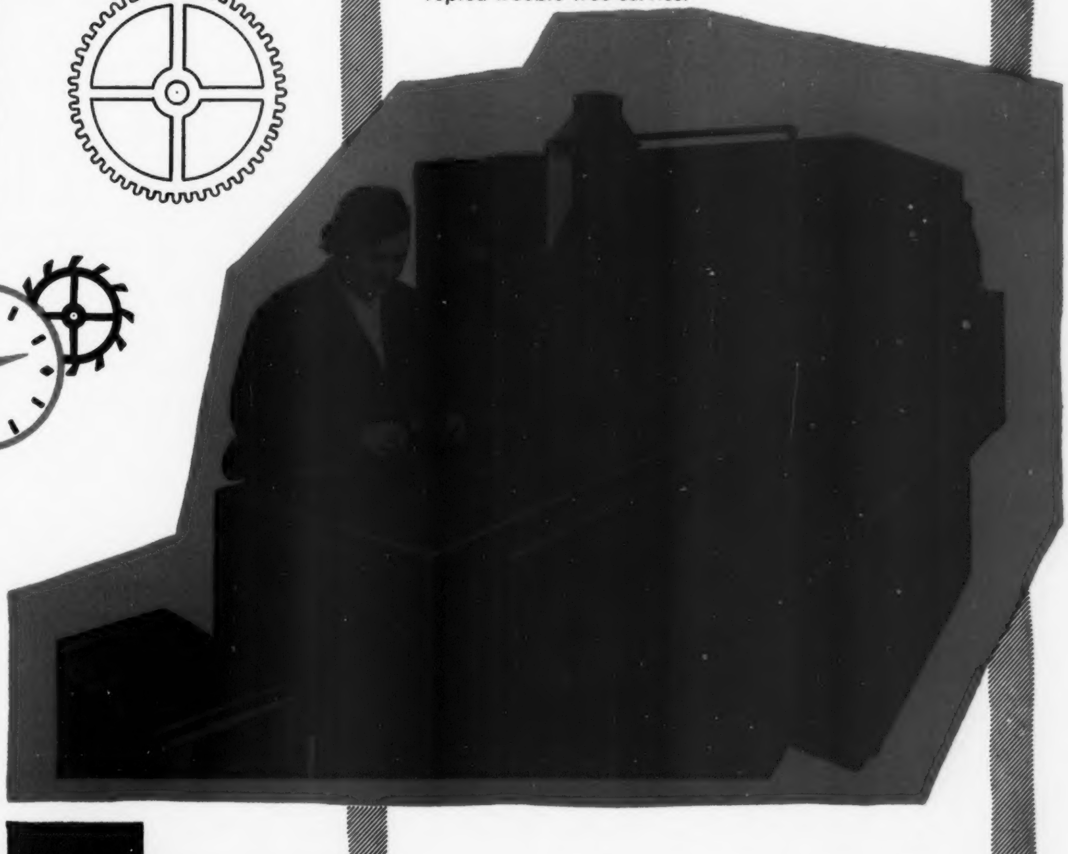
THE JOURNAL OF
THE INSTITUTION OF
PRODUCTION ENGINEERS

10 Chesterfield Street
Mayfair : London : W.1
Telephone GROsvenor 5254-9


HORSTMANN


ACME.

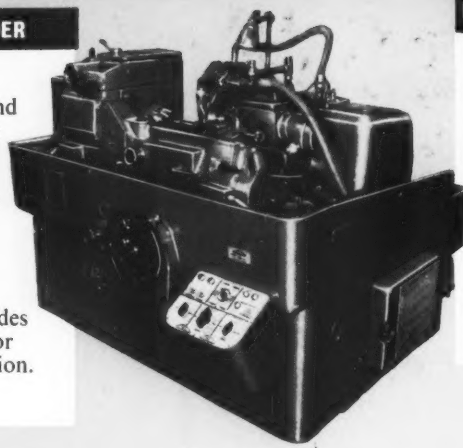

Schuler
1839—1959
SCHULER
the most modern Machine Tools for Sheet Metal Working
PEARSON PANKE LTD
1-3 HALE GROVE GARDENS, LONDON, N.W.7
Telephone: Mill Hill 3232. Telex 23273
SCHULER
SCHULER
SCHULER
L. SCHULER AG GOEPPINGEN




JIG BORING
MACHINES
OPTICAL INSPECTION
EQUIPMENT
THE NEWALL GROUP
stand
41
jig boring
grinding and
lapping machines
optical
inspection and
air gauging equipment
stand
506
AUTOMATIC MACHINE
CONTROL EQUIPMENT
LAPPING MACHINES
INTERNATIONAL MACHINE TOOL EXHIBITION
OLYMPIA LONDON 25th JUNE — 8th JULY 1960
GRINDING
MACHINES

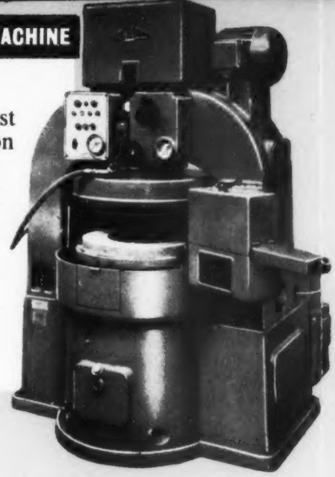
N L THREAD GRINDER

Unexcelled accuracy and operating economy are features of Newall thread grinders designed for tool room or production work. Capacity—20″ or 32″ between centres, 10″ maximum grinding diameter. Range includes fully automatic units for large scale tap production.

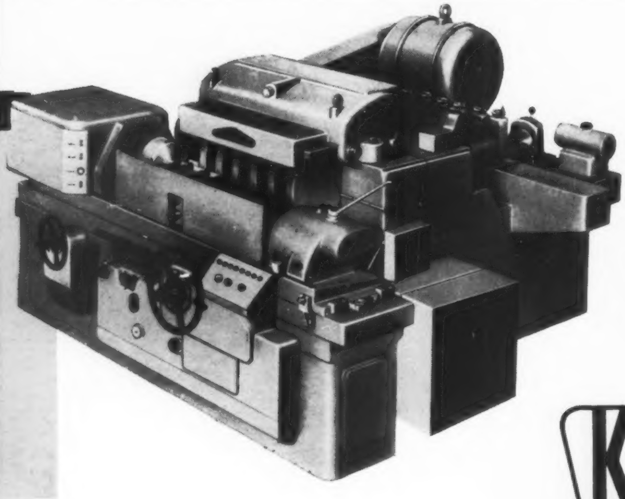


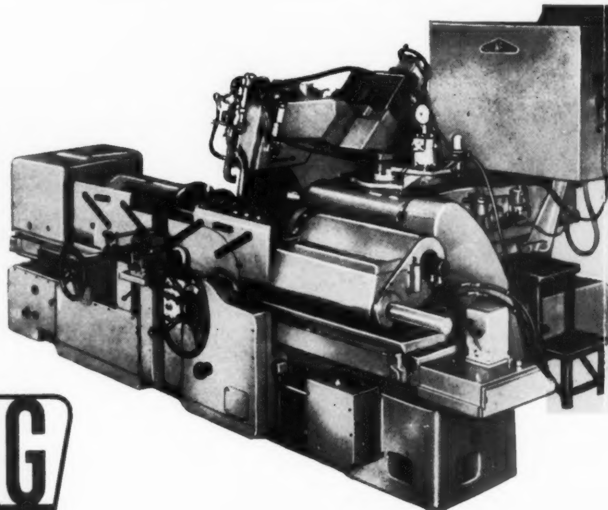
RIGIDLAP LAPPING MACHINE

An extremely robust model for production of high quality flat or cylindrical components up to $2\frac{1}{2}''$ thick × 7″ square or $2\frac{1}{2}''$ diameter × 7″ long. Smaller machines are also available.



STANDARD & AUTOMATIC GRINDERS–LAPPING MACHINES–FINE BORERS





KG

HAC

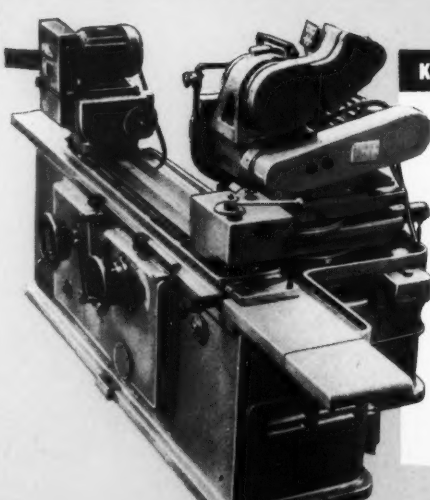
This
rapic
ances
pin
mode
prod
autor
in-lir

Size
A ho
desig
line
also

AJOR CASTINGS PRODUCED BY MEEHANITE METAL PROCESS

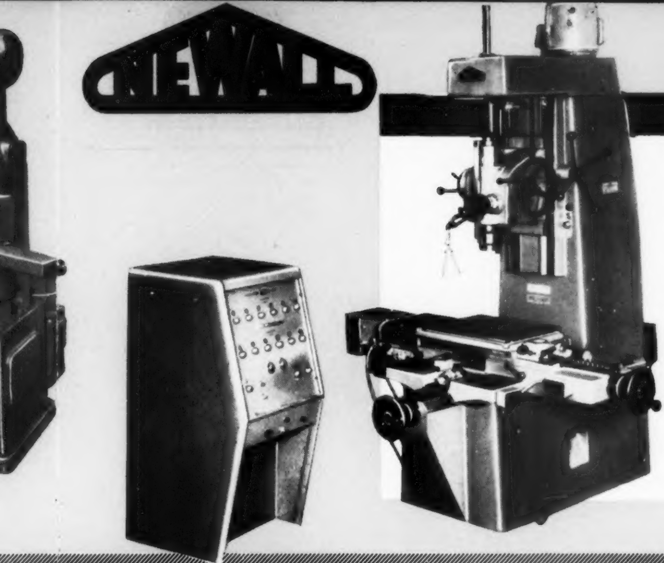
FINE BORING MACHINE

Designed for high speed, automatic production of components by single or multi-point tooling. Available with single or double heads and auxiliary cross-slide. Table size $15\frac{3}{4}'' \times 22\frac{3}{4}''$.



KU UNIVERSAL GRINDER

Sturdily built to the highest standards of precision, these fully universal machines provide facilities for external, internal and face grinding. 25 models available in sizes ranging from 8″ × 20″ to 24″ × 96″



MODEL 1520 JIG BORING MACHINE

This low-priced high precision machine is offered with three alternative measuring systems—Newall roller and micrometer, precision screw and vernier, or optical. By either method table settings to 0·00005″ can be made. Worktable size 15″ × 20¾″ ; spindle speeds 67 to 3,000 r.p.m. ; spindle speeds (up and down) ·0015″, ·003″, ·006″ per spindle revolution. An auto-positioning version is also available. Shown in the accompanying illustration, this unit is equipped with the Airmec measuring and control system to give improved production times where an overall accuracy of ·0005″ is adequate. In addition, the machine incorporates either the Newall roller or optical measuring systems for close tolerance work and is equipped with table milling feeds.

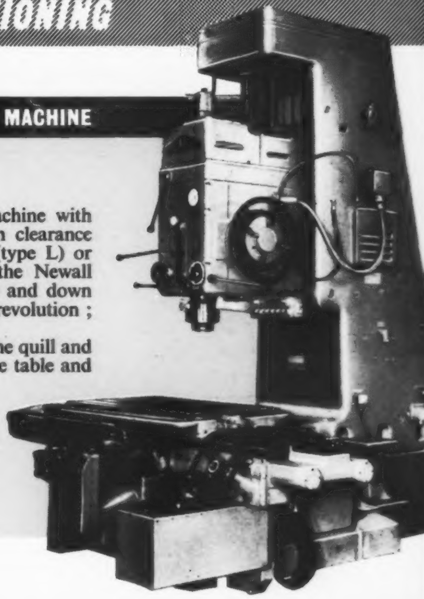
ERS STANDARD & AUTOMATIC POSITIONING

HAC CRANKPIN GRINDER

This machine is designed for rapid production to close tolerances and high grade finish of pin diameters. An alternative model developed for large-scale production incorporates a fully automatic cycle for grinding in-line pins.

Size range 16″ swing × 48″ to 72″. A heavy duty 28″ × 84″ machine designed for grinding both main line journals and crankpins is also offered.

MODEL 2451 JIG BORING & MILLING MACHINE

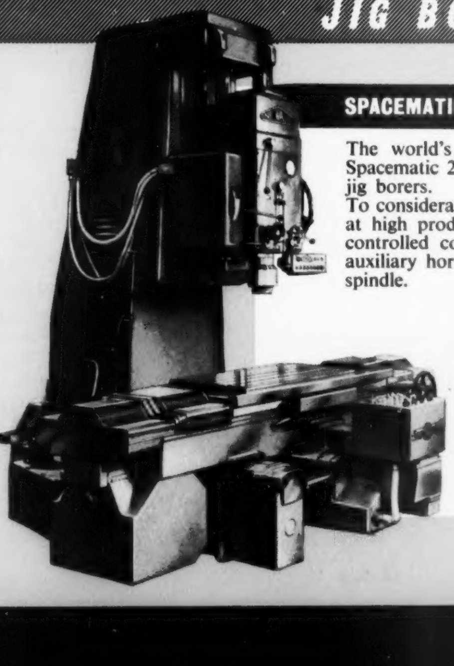


A large capacity tool room or production machine with 24″ × 51″ worktable and providing a maximum clearance between spindle nose and table of either 31″ (type L) or 48″ (type H). Table settings to ·00005″ by the Newall roller measuring system or optical system ; up and down spindle feeds from ·0005″ to ·012″ per spindle revolution ; spindle speeds 0 to 2,000 r.p.m.
Other features include rapid electric traverse of the quill and quill head together with hydraulic traverse of the table and cross-slide for milling purposes.
An auxiliary horizontal boring spindle is available for use with this fine quality machine.

ESS JIG BORING & MILLING MACHINES

INDER

lt to
stan-
sion,
ersal
vide
s for
ernal
ling.
able
ging
″ to
96″

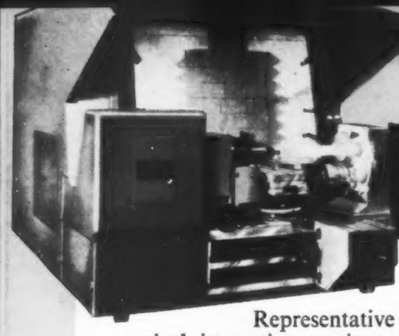


SPACEMATIC 2657 AUTO-POSITIONING JIG BORING & MILLING MACHINE

The world's most versatile numerically controlled high-precision machine tool, the Spacematic 2657 cuts production times by up to 80% in comparison with conventional jig borers.
To considerably extend its basic field of employment for accurate jig boring and milling at high production rates, the machine is also offered with a two-dimensional, tracer-controlled copy milling attachment, automatic profile generation equipment, and an auxiliary horizontal spindle.

Abridged specification :—Table size 26″ × 57″ ; spindle speeds 0-2,000 r.p.m. ; spindle feeds (8 up and down) from ·0005″ to ·012″ per spindle revolution ; dimension selection to ·0001″ by manual setting dials or automatic punched card reader.

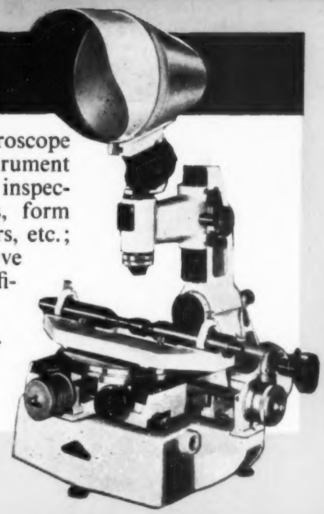
OMT



MODEL WP 100 LARGE CAPACITY PROJECTOR

Representative of high precision optical inspection equipment manufactured by Optical Measuring Tools Ltd., model WP100 Large Capacity Projector with a 60" ×40" viewing screen and a magnification range from 10x to 100x is equipped for both contour and surface inspection.

TOOLMAKERS MICROSCOPE



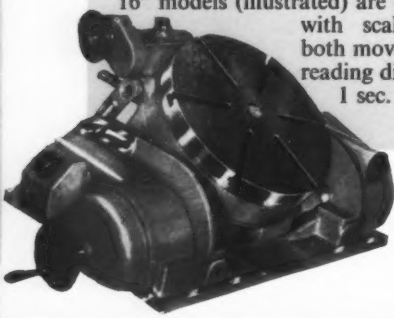
The Toolmakers' Microscope is a high accuracy instrument designed to simplify inspection of thread forms, form tools, templet contours, etc.; interchangeable objective systems provide magnifications up to 100x.

O.M.T. also manufacture optical comparators, linear and roundness measuring machines, projection pantometers, optical dividing heads.

OPTICAL INSPECTION EQUIPMENT-OPTICAL ROTARY TABLES

OMT OPTICAL ROTARY & INCLINABLE TABLES

Available with 8", 12" or 16" platens, these sturdy, high-precision units are designed to facilitate machining or inspection of components featuring compound angles. The 12" and 16" models (illustrated) are offered with scales for both movements reading direct to 1 sec. of arc.

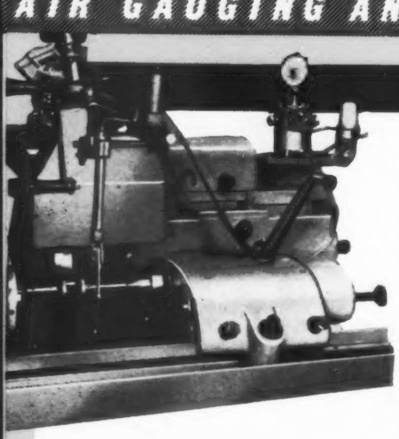


OMT OPTICAL ROTARY TABLES

Designed for a wide variety of machining and inspection purposes, the range includes models with 10", 16" and 30" platens ; scales of the two larger models read direct to 1 sec. of arc.

The 30" table illustrated is also available with E.M.I. tape controlled auto-positioning system.

AIR GAUGING AND MACHINE CONTROL EQUIPMENT.



AUTOMATION HEAD

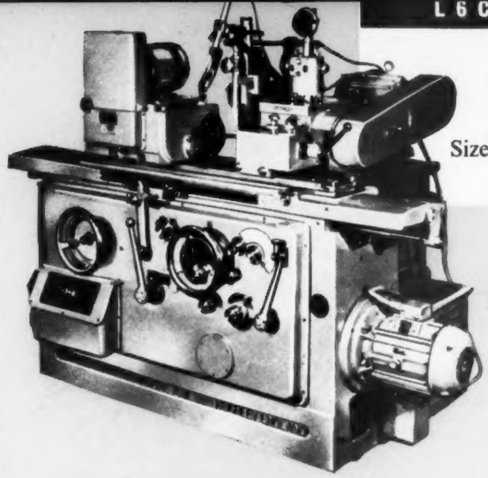
A wide range of equipment for precise control of size and machine operating cycles is offered. Illustration (left) shows a Newall-Keighley cylindrical grinder with final feed, component finish diameter and wheel-head withdrawal controlled through workpiece contact by an OMT-ETAMIC Automation Head.

AIR GAUGING EQUIPMENT

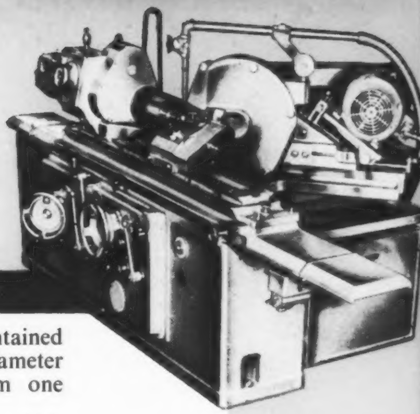
Unrivalled for accuracy and long-term reliability, OMT-ETAMIC air gauging equipment is simple to use and requires little maintenance. Comparator units (left) for internal or external measurement with a gauging accuracy from ·00005" to ·0000062" are available; multi-gauging systems with or without automatic feed, acceptance and rejection mechanisms are devised to users' requirements.

OMT-ETAMIC

L 6 CYLINDRICAL GRINDER



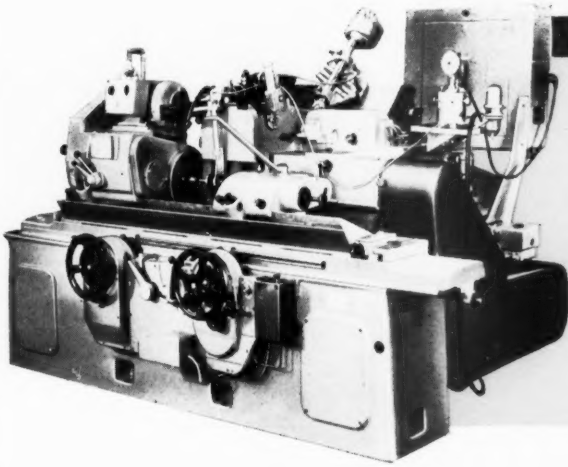
A high precision tool room or production machine for plunge or traverse grinding. Size—6″ swing by 18″ or 24″.



L 12 ANGLE HEAD GRINDER

A sturdily built, self-contained unit for grinding a diameter and adjacent face from one setting.
Size—12″ swing by 24″ to 72″.

CYLINDRICAL-INTERNAL-UNIVERSAL-THREAD-CRANKSHAFT-CAMSHAFT



LA CYLINDRICAL GRINDER

A heavy duty production machine, this model is supplied with either 12″ or 16″ swing in the range 24″ to 120″ between centres. Features include wheelhead-mounted hydraulic form dresser and automatic wheel truing compensation—up to 10″ wide wheels accommodated. Fully automatic units and machines equipped with work feed mechanisms for 'link- line' production are also available.

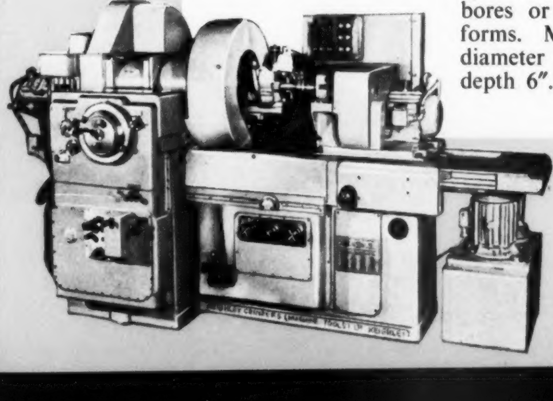
MAC MULTI WHEEL GRINDE

This heavy duty machine equippe with a wheelhead-mounted, hydraul cally operated dresser is designed t grind in one operation componen with a number of diameters; grindin journals of crankshafts or camshaf are typical applications. Th machine has a 12″ swing with 4 capacity between centres and t wheel spindle accommodates whee up to 36″ diameter over a maximu span of $32\frac{1}{2}$″.

BUILT TO J.I.C. ELECTRIC & HYDRAULIC STANDARDS—ALL

K 4 AUTOMATIC INTERNAL GRINDER

Fully automatic and single lever controlled after setting-up, this machine is arranged for gauge or diamond sizing and is unsurpassed for accuracy, finish and high output rate of components with cylindrical bores, taper bores or internal cam forms. Maximum hole diameter 6″, maximum depth 6″.



K 1 INTERNAL GRINDER

A high-precision, self-contained unit designed for producing bores within the range $\frac{1}{16}$″ to $1\frac{5}{8}$″ diameter, this machine is offered with a variety of spindles covering speeds up to 100,000 r.p.m.

NEWALL

worldwide representation...

THE NEWALL GROUP

THE NEWALL ENGINEERING CO., LTD.

HIGH STREET OLD FLETTON PETERBOROUGH NORTHAMPTONSHIRE

Telephone: Peterborough 3227. Cables and Telegrams: 'Precision' Peterborough

OPTICAL MEASURING TOOLS LTD.

OLDFIELD HOUSE BRIDGE ROAD MAIDENHEAD BERKSHIRE

Telephone: Maidenhead 3704. Cables and Telegrams: 'Optool' Maidenhead

KEIGHLEY GRINDERS (MACHINE TOOLS) LTD.

AIREWORTH ROAD KEIGHLEY YORKSHIRE

Telephone: Keighley 4294. Cables and Telegrams: 'Kagee' Keighley

THE NEWALL PRECISION FOUNDRIES LTD.

PHOENIX FOUNDRY HEAP BRIDGE BURY LANCASHIRE

Telephone: Bury 3904. Cables and Telegrams: 'Newall' Bury

THE NEWALL MACHINE TOOL CORPORATION OF CANADA LTD.

ROOM 306 68 YONGE STREET TORONTO ONTARIO

Telephone: Empire 6-9832. Cables and Telegrams: 'Newtool' Toronto

Our manufacturing programme

JIG BORING MACHINES

STANDARD MACHINES

Model 1520 Table size 15"x$20\frac{3}{4}$"
Model 2443 Table size 24"x43"
Model 2451 Table size 24"x51"

AUTO-POSITIONING JIG BORING AND MILLING MACHINES

Spacematic 1520 Table size 15"x$20\frac{3}{4}$"
Spacematic 2657 Table size 26"x57"

GRINDING MACHINES

Cylindrical* 4"x18" to 16"x120"
Internal* up to 15" swing
Universal 8"x20" to 24"x96"
Thread* 8"x20" and 8"x32"
Camshaft* 6"x24" to 6"x48"
Crankpin* 16"x48" to 24"x84"
Turbine Blade
Multi-wheel

* Standard or automatic machines equipped with workfeed mechanisms to user's requirements

OPTICAL INSPECTION EQUIPMENT

Optical Comparators
Toolmakers Microscopes
Projection Pantometers
Workshop Projectors
Optical Rotary Tables
Optical Dividing Heads
Linear Measuring Machines
Roundness Measuring Machines

LAPPING MACHINES

Universal machines in 3 sizes

AIR GAUGING EQUIPMENT

OMT-ETAMIC high precision air gauging units.
Multi-gauging and machine control equipment.

sales organisation:— NEWALL GROUP SALES LTD PETERBOROUGH ENGLAND

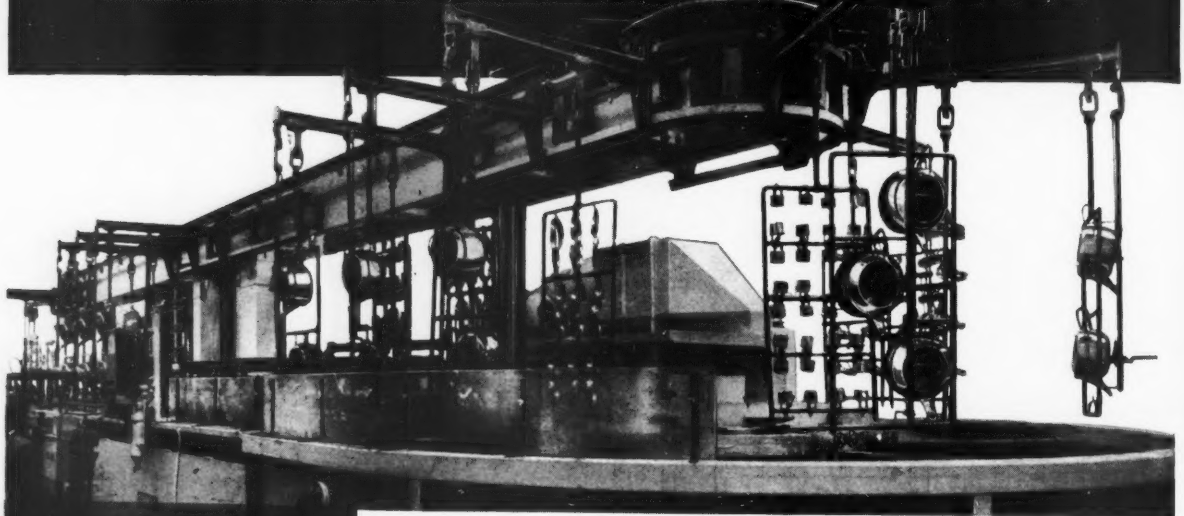
TELEPHONE: PETERBOROUGH 3227. CABLES: 'PRECISION' PETERBOROUGH

J

La
th
fa

NEWALL
MODEL 1520
JIG BORER
Latest development of the team that produced the 'Spacematic'—acknowledged to be the world's fastest and most accurate jig boring machine.
HIGH PRECISION
AT
LOW PRICE
FULL DETAILS ON REQUEST TO:
NEWALL GROUP SALES LIMITED
PETERBOROUGH ENGLAND · TELEPHONE: PETERBOROUGH 3227

CANNING Automatic ELECTROPLATING PLANT....



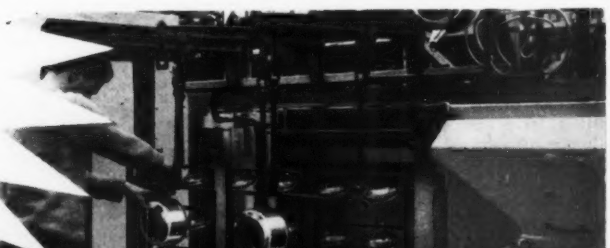
Chosen by....

Hotpoint

. . . for the quality finishing of their high-class electrical products.

The efficiency of the new "Trojan" automatic plating plant — which is for copper, nickel and chrome — has enabled Hotpoint to practically double their plating capacity while still further improving the exceptionally high standard of finish for which their products are renowned.

The change-over from manual to automatic plating was made without loss of production.



W. CANNING & CO. LTD. BIRMINGHAM 18. LONDON · SHEFFIELD & AUSTRALIA

OA/6085

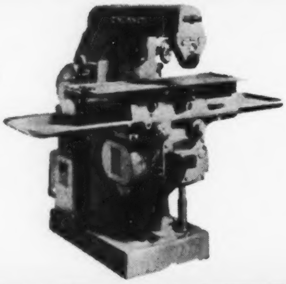
Interested
in
electronic

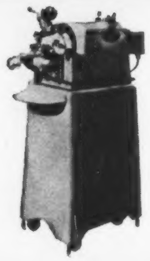
MACHINE TOOLS DIVISION

CHARLES CHURCHILL

CINCINNATI Milling Machines Ltd.

Precision machine tools for toolroom milling, manufacturing milling, cutter sharpening, surface broaching, profiling, die-sinking and many related machining operations.



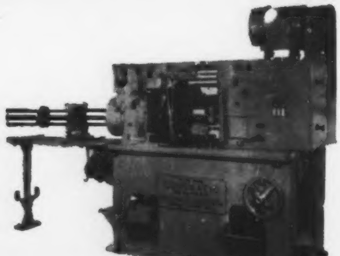


CINCINNATI Milling Machines Ltd.

Milling machines of all types in three styles—plain, universal and vertical, including the famous dial type machines. Machines for toolroom, production and general purpose. Also the revolutionary 'Spiropoint' drill point grinder.

PETERMANN S. A. Jos. Petermann

Automatics including the new P7 machine with turret and 'Variator' electronic camshaft speed control. The range covers machines to produce small screws such as required for spectacle frames as well as machines having capacity for 1 inch bars. Pinion and gear cutters, tap flute millers and tool sharpeners.



CONOMATIC Cone Automatic Machine Co. Ltd.

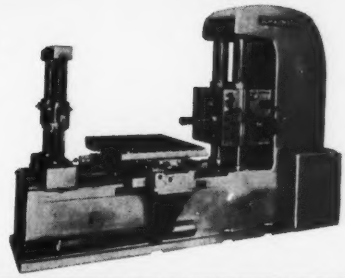
Single and multiple spindle automatics, the latter of 4, 6 and 8 spindle bar & chucking types up to 9¾″ capacity chucking.
The advantages of the 'Cone' type of construction are extended to the 4HI machine.

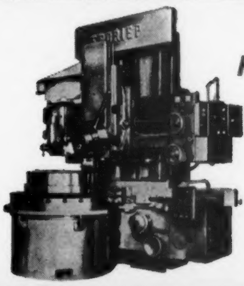
VERTIMAX Limited

Vertical spindle chucking lathes 24″ swing and twin slides. High production or batch type production for which profiling attachments are available.
Also Churchill Curtis abrasive belt through feed grinders.

SCHARMANN & Co. GMBH

A range of boring machines floor & table types up to 5″ spindle with new optical positioning control. Tape and digital control systems are also available.



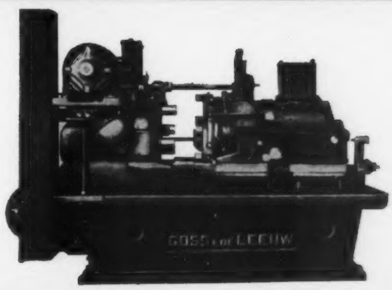


FRORIEP GMBH

Heavy duty and roll turning lathes. Large boring machines, traversing column type, also vertical, single and double column types 3/25ft. table. Plate edge planing, straightening and bending machines.

GOSS AND DE LEEUW Machine Co.

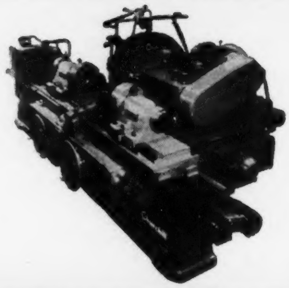
4 spindle work rotating and tool rotating automatic chucking machines and the 1-2-3 Tool rotating Automatic chucker.



CHARLES CHURCHILL

CHURCHILL Machine Tool Co. Ltd.

Complete comprehensive range of grinding machines of all types. Plain, universal, centreless, internal (automatic and cylinder) camshaft, crankshaft, roll grinders, splineshaft.



SUPFINA (Wieck & Hentzen)

Machines for superfinishing round parts by the centreless method (through feed and plunge cut) and attachments for use on standard centre lathes (single or multiple stoneholders) Camshaft and taper pin super finishing.

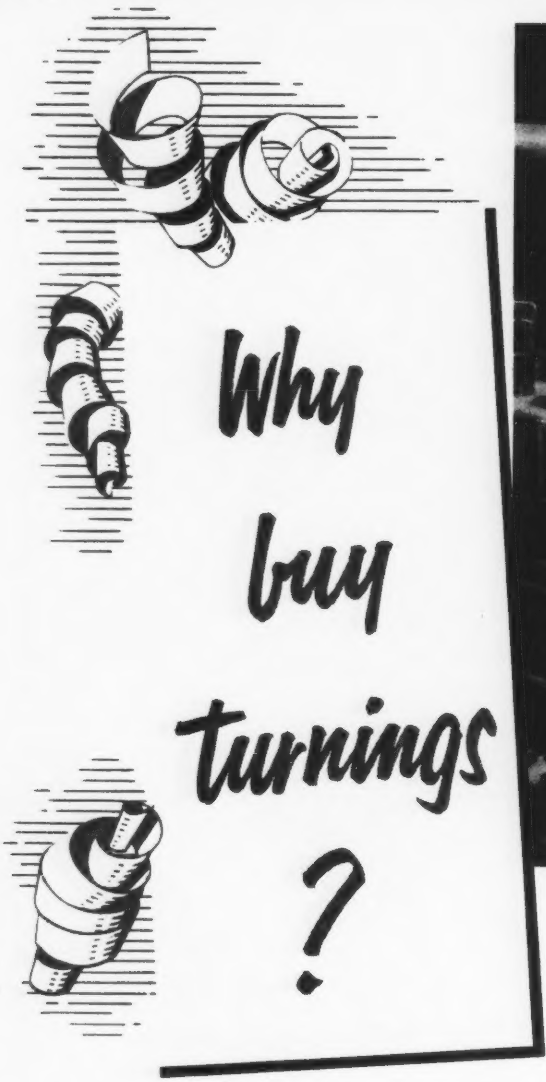
ENGINEERS SUPPLIES

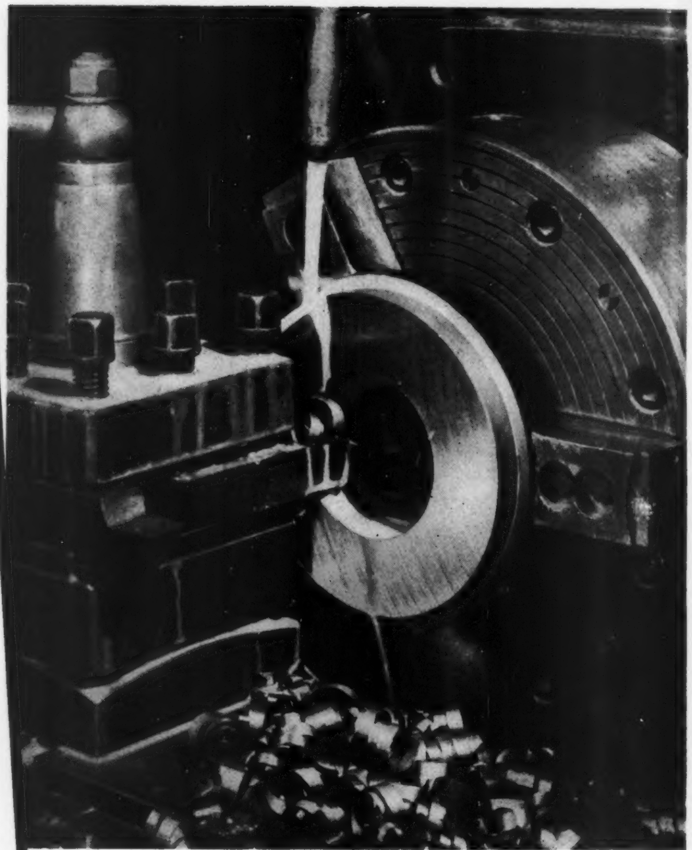
One quality — top quality

Blu-Mol Hacksaw Blades · Carborundum Grinding Wheels and Abrasives · C.G.M. Tip Tools · Dormer Drills and Cutting Tools · Eclipse Magnetic Chucks · E.S.C. Gear Hobs and Files · E.S.T. Plug Gauges · Jacobs Drill Chucks · Lehmann, Archer & Lane Taps and Dies · Pratt Lathe Chucks · Record Vices · Unbrako Socket Screws.

CHARLES CHURCHILL & COMPANY LIMITED
Coventry Road, South Yardley, Birmingham 25
Branches at London, Glasgow, Newcastle and Manchester


The finest from all points of view
M&C
TRADE MARK
Monks & Crane Ltd
BIRMINGHAM
LONDON MANCHESTER GLASGOW NEWCASTLE-ON-TYNE LEEDS BRISTOL
Socket Screw Products
HK Distributors for





Why pay for excess material which you will only have to machine away? Buy shell-moulded precision steel castings and save. SAVE on weight, on machining, on wastage. This special moulding process offers you accuracy (with no need for excessive machining allowances), better surface finish and uniformity, valuable aids to your production set-up.

EDGAR ALLEN

Visit **STAND 505** at the INTERNATIONAL MACHINE TOOL EXHIBITION, Olympia, 25th June to 8th July, to see our latest range of Engineers' Tools.

* Shell-moulded precision steel castings

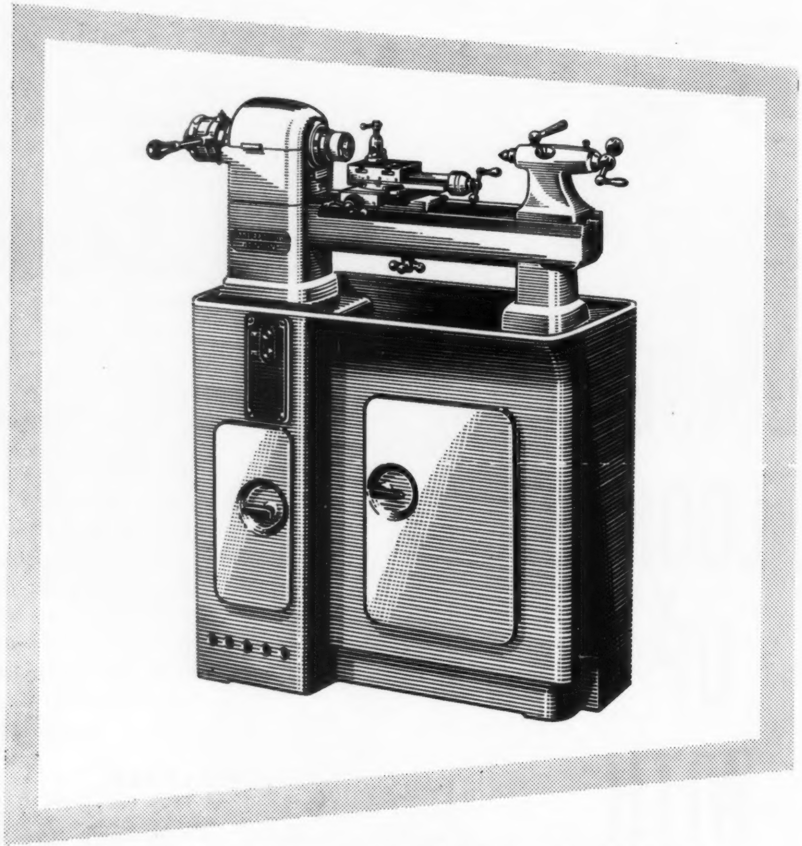
EDGAR ALLEN & CO. LIMITED
IMPERIAL STEEL WORKS · SHEFFIELD 9

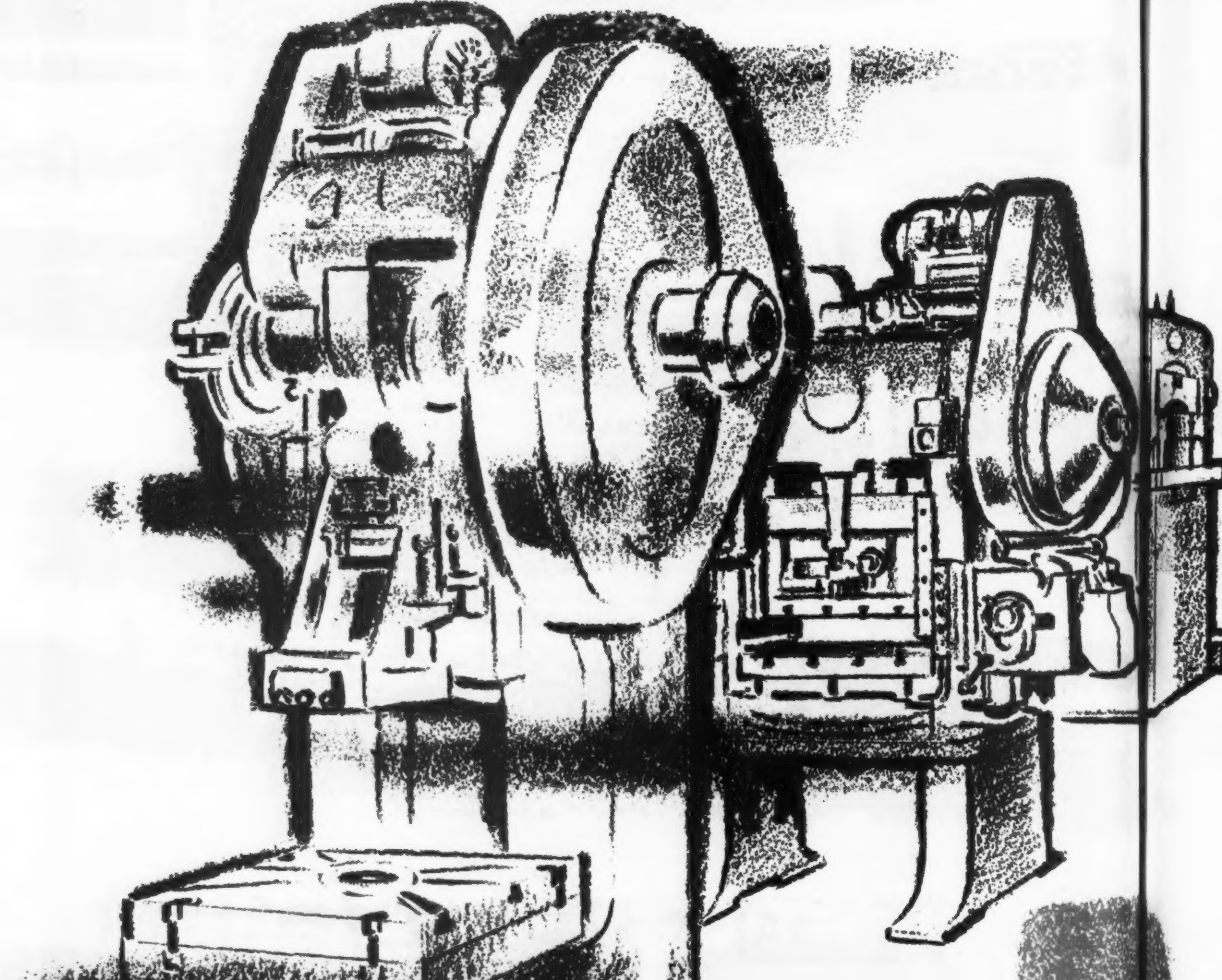
** Weight range from ¼ oz. up to 10 lb.*

TS32/PE

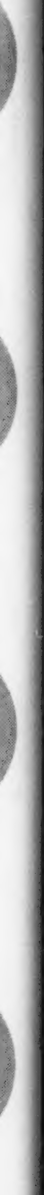
To: EDGAR ALLEN & CO. LIMITED, SHEFFIELD 9
Please send data on Shell-moulded Precision Steel Castings to:

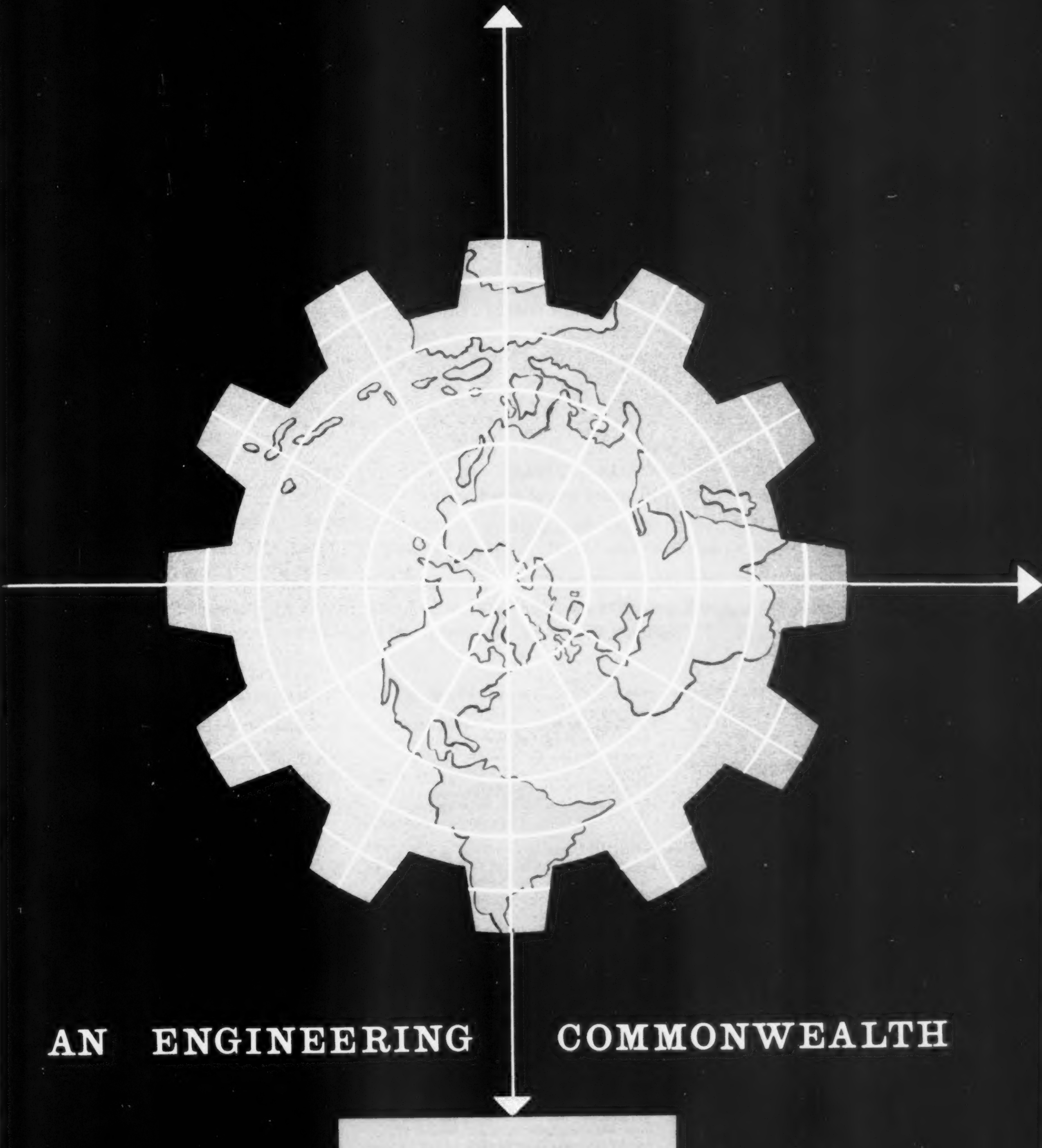
NAME ....
POSITION ....
FIRM ....
ADDRESS ....
....





er





Wickman Check List of Exhibits

HIGHLIGHTS

Stand 68
Grand Hall Annexe

New WICKMAN 3¼ in. 6-SPINDLE BAR AUTOMATIC. ● WIMET TOOLING on all Wickman Automatics and faster than ever cycle times. ● Automatic loading and discharging on WICKMAN 6⅝ in. CHUCKING AUTOMATIC. ● New side-loading feature on WICKMAN BAR AUTOMATICS. ● New fully automatic WICKMAN-SCRIVENER DUPLEX PERIPHERAL GRINDING MACHINE. ● New WICKMAN-SCRIVENER CENTRELESS GRINDER, NO. I, of 3 inch capacity with automatic loading, gauging and discharging. ● New four-sequence centreless grinding technique on WICKMAN-SCRIVENER NO.3 with automatic gauging and wheel dressing. ● Power operated turret on WEBSTER AND BENNETT BORING MILL. ● Liftveyor locating and transferring attachment applied to ELDAIR PLATE SHEAR. ● Cold extrusion of steel components on MAYPRES 300 TONS PRESS. ● New technique for high-speed tube bending demonstrated on NEW PINES PRESS BENDER. ● Gripper feed inclinable high-production WEINGARTEN BLANKING PRESS. ● New COLLET AND ENGELHARD HORIZONTAL BORING AND FACING MACHINE with many special new features promoting high accuracy. Automatic positioning by photo-electric cells.

Stand 69
Grand Hall Annexe

New WICKMAN ERODOMATIC DIE MACHINE for the semi-automatic production and servicing of large forging dies by spark-machining.

STAND 68 GRAND HALL ANNEXE

WICKMAN 1 in. 6-spindle bar automatic incorporating tapping, undercutting, spline broaching, drilling, forming, cutting-off and standard chasing, and tooled with tungsten carbide.

WICKMAN 1¾ in. 6-spindle bar automatic, incorporating roller box turning on three diameters, diehead thread rolling, serration rolling, tooled with tungsten carbide.

WICKMAN 3¼ in. 6-spindle bar automatic, incorporating turning, forming, milling, internal recessing and cutting-off, and tooled with tungsten carbide.

WICKMAN 6⅝ in. 6-spindle chucking automatic, fitted with automatic loading and discharging to produce a Hub Driving Member.

WICKMAN Optical Profile Grinding Machine.

WICKMAN-SCRIVENER 618 and 824 Surface Grinding Machines.

WICKMAN-SCRIVENER No. 0 Centreless Grinding Machine.

WICKMAN-SCRIVENER No. 1 Centreless Grinding Machine.

WICKMAN-SCRIVENER No. 3 Centreless Grinding Machine.

WICKMAN-SCRIVENER 36DPG Duplex Peripheral Grinding Machine.

WEBSTER & BENNETT 36 in. D.H. Boring and Turning Mill.

WEBSTER & BENNETT 48 in. Boring and Turning Mill, with Electronic Profile Turning Equipment.

WICKMAN-MOULTON Universal Thread Milling Machine.

ELDAIR Plate Shear, capacity 8 ft. by ½ in. With Liftveyor Automatic Locating and Transferring Device.

ELDAIR Press Brake Type 8/110.

COLLET & ENGELHARD BFf 85n Horizontal Boring and Milling Machine.

COLLET & ENGELHARD Automatic Cutter Head Grinder.

DAVENPORT Model B Multiple-spindle Automatic Screw Machine.

HERLAN P.5 Impact Extrusion Press.

KLINK Vertical Broaching Machine RIV 8-00D.

KLINK Vertical Broaching Machine RIV 4-06.

KLOPP 650 H Fully Hydraulic High Speed Shaping Machine.

KLOPP 850 H Fully Hydraulic High Speed Shaping Machine.

LORENZ S.7/500 Automatic High Speed Gear Shaping Machine.

LOSENHAUSENWERK UA-300A Universal Balancing Machine.

LOSENHAUSENWERK SAE 40 Vertical Axis Single Plane Balancing Machine, with drilling unit for compensation of component on the machine.

LOSENHAUSENWERK UA 3 Balancing Machine.

MAYPRES Universal Toggle Press, open type frame Model MKN 1-63/6.

MAYPRES Cold Forming Press Model MKR 300/20-32.

NAXOS-UNION W. 500/2000 Roll Grinding Machine.

ORTLIEB Model OSIIA Twist Drill Grinding Machine.

PINES Hi-Speed 3T Press Bender for tubes.

TIBO-YODER Roll Forming Machine, Type M-1½.

WEINGARTEN P.140 Percussion Screw Press.

WEINGARTEN Type H.Z50 Inclinable High Production Automatic Blanking Press.

WEINGARTEN XAF High-Speed Notching Machine.

WEIPERT Precision Engine Lathe, Type W.G.480, with screw cutting attachment.

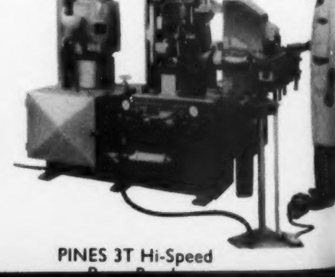
STAND 69 GRAND HALL ANNEXE

WICKMAN Erodomatic W/DM Die Machine. Specifically designed for the semi-automatic production and servicing of forging dies up to a maximum size of 28 × 16 × 15 in. deep. Area of work table 32 × 20 in.

WYSSBROD B.57
Horizontal Boring Machine

SCHAUBLIN 20
Rotary Transfer Machine

HAUSER No. 5.
Jig Boring Machine



PINES 3T Hi-Speed

International Machine Tool Exhibition

OF THE SHOW

Programme-controlled HELLER TURRET-TYPE DRILLING MACHINE. ● New HELLER BED-TYPE MILLING MACHINES. ● NAGEL TRANSFER-LINE HONING UNIT for valve guide bores in cylinder blocks. ● Superfinishing shock absorber pistons on THIELENHAUS CENTRELESS AUTOMATIC.

Stand 65
Grand Hall Annexe

DUBIED FULLY AUTOMATIC COPYING LATHE with multi-tool set up. ● Short-batch automatic screw machining from standard cams on GYGI AUTOMATIC. ● New HAUSER NO. 5SM JIG GRINDING MACHINE. ● New HAUSER NO. 5 HIGH PRECISION JIG BORER. ● New MIPSA SEMI-AUTOMATIC PRODUCTION GRINDING MACHINE. ● New SCHAUBLIN ROTARY TRANSFER MACHINE for short or long series production. ● New SCHAUBLIN SEMI-AUTOMATIC CAPSTAN LATHE. ● New WYSSBROD SEMI-AUTOMATIC PRODUCTION BORING MACHINE. ● New WYSSBROD AUTOMATIC hydraulic copying and spiralling production milling machine.

Stand 524
Empire Hall 1st. Floor

New range of WICKMAN WIMET ECONOTIP TOOLS incorporating quick-change 'throwaway' tip device.
● New range of FACE MILLING CUTTERS IN THE ECONOTIP RANGE with 'throwaway' Wimet tips.
● SENDZIMIR and CMP rolls for cold rolling.

DIAMOND WHEEL DEMONSTRATION—This demonstration will compare metal removal capacity of natural and treated diamonds in diamond impregnated wheels, used for carbide grinding.

Stand 520
Empire Hall Gallery

WICKMAN Erodomatic W/SM, Series III. Area of work table, 16 in. × 12 in. Distance quill to table, 26 in. Maximum workpiece area, 29 in. × 18 in.
WICKMAN Erodomatic W/UV. A universal machine with additional servo-controlled work-head movements. Area of work table 10 in. × 7 in.; distance quill to table 12 in.; maximum workpiece area, 14 in. × 9 in.
WICKMAN Erodomatic W/BM. For bench mounting or with cabinet stand. Area of work table 8 in. × 5 in. Distance quill to table 13 in.
THE WICKMAN Impregnator. A portable unit for the carbide impregnation of steel cutting tools and dies.

STAND 65 GRAND HALL ANNEXE

HELLER Horizontal (Bed-type) Milling Machine, PFH 100/1.
HELLER Vertical Milling Machine FV/160.
HELLER Turret-type Drilling Machine with Programme Control for work-positioning and for Turret Indexing, SBR 32.
HELLER SSH 500 Automatic Cold Circular Sawing Machine.
HELLER KA 315 Automatic Cold Circular Sawing Machine.
HELLER SA 315 Sawblade Grinding Machine.
NAGEL Four Spindle Transfer Line Honing Unit, TS.104-2.
THIELENHAUS Centreless Microfinish Machine SF 125.

STAND 100 NATIONAL HALL

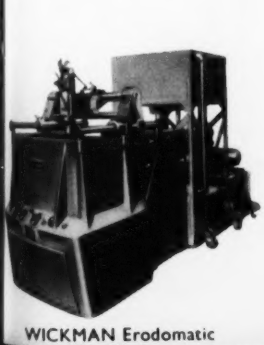
HEENAN S. 1¼ Multiform demonstrating the production of piece parts from strip by the multiform technique.
HEENAN S.3 Multiform.

STAND 520 EMPIRE HALL GALLERY

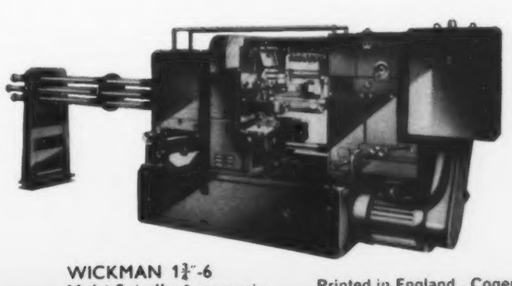
WICKMAN WIMET Tungsten Carbide Cutting Tools and Wear-Resistant Parts including: brazed and mechanically held Lathe and Planer Tools, Milling Cutters, Drills and Reamers, Round and Shaped Wire, Bar and Tube Dies, Hollow-ware Drawing Dies, Press Tools, Heading Dies, Special Purpose Tools, Instrument Parts, Wear-resisting Machine Parts, and Woodworking Tools. Wickman Sintered Oxide Inserts.

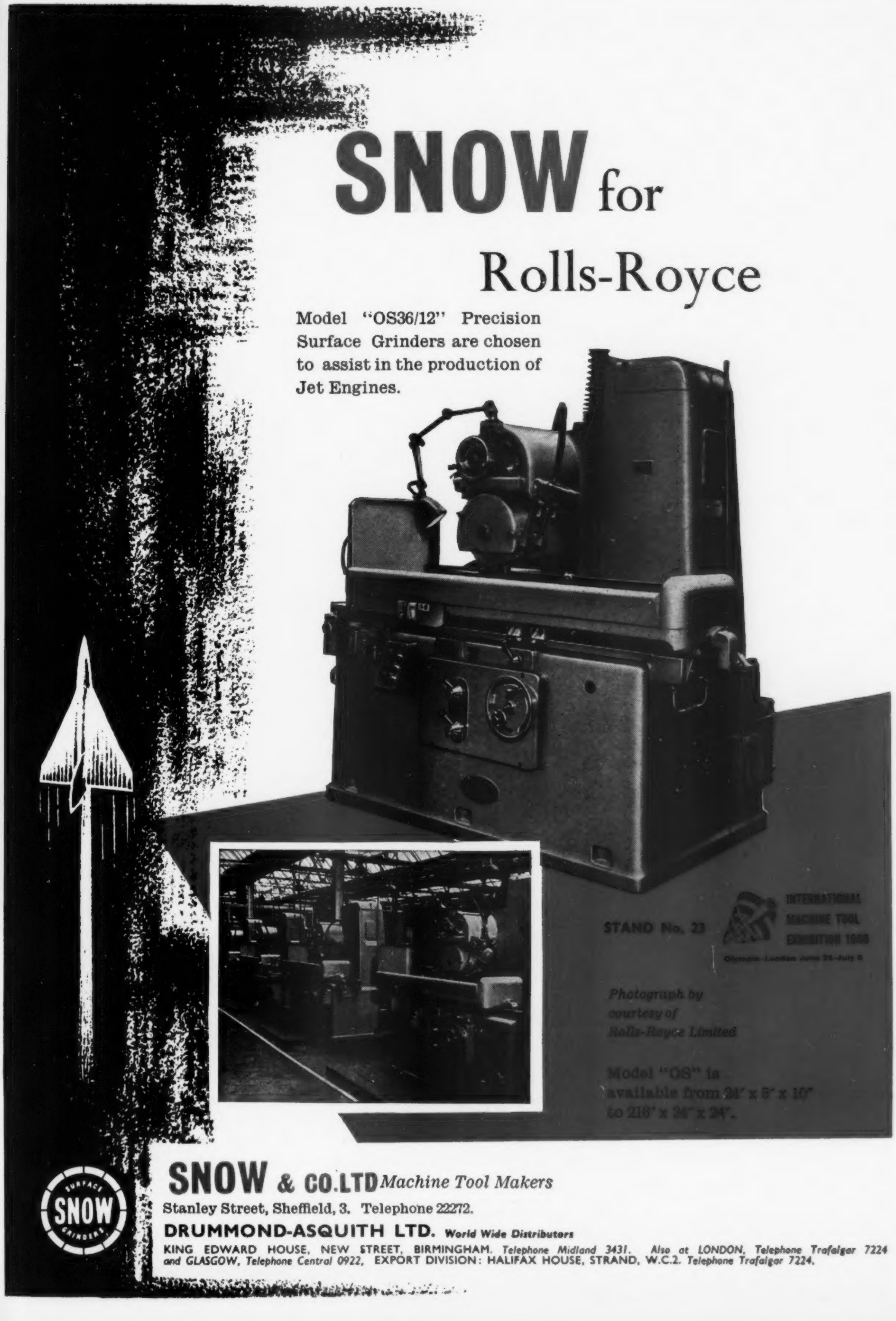
STAND 524
EMPIRE HALL FIRST FLOOR

DUBIED 515/650 Rapid Copying Lathe.
DUBIED 517/650 Rapid Copying Lathe.
GYGI Precision Turning and Screw Cutting Automatic GL.16-10.
HARO No. 12 Universal Tool-cutter Precision Grinding and Sharpening Machine.
HARO No. H.400 Automatic Milling Cutter Grinding Machine.
HAUSER 3BA Jig Boring Machine.
HAUSER Type 5 Precision Jig Boring Machine.
HAUSER Type 3SM Jig Grinding Machine.
HAUSER P.125 Profile Projector.
HAUSER Type 5SM Jig Grinding Machine.
MIPSA ACTD Universal High Precision Grinding Machine.
MIPSA RPS Production Cylindrical Grinding Machine.
SCHAUBLIN S.13 Universal Toolroom Milling Machine.
SCHAUBLIN S.53 High Precision Universal Milling Machine.
SCHAUBLIN 102.VM Lead Screw Lathe.
SCHAUBLIN SV.20 Rotary Transfer Machine.
SCHAUBLIN 102 High Precision Turret Lathe, with Hydro-pneumatic Automatic Feed Unit.
SCHAUBLIN 102 High Precision Second Operation Lathe.
WYSSBROD 125/11A Wheel and Pinion Cutting Machines. Two machines to be shown; one with vibratory hopper feed, the other with automatic magazine loading.
WYSSBROD Model V Automatic Milling Machine for straight or spiral fluted taps, reamers and cutters.
WYSSBROD B.57 Horizontal Boring Machine.

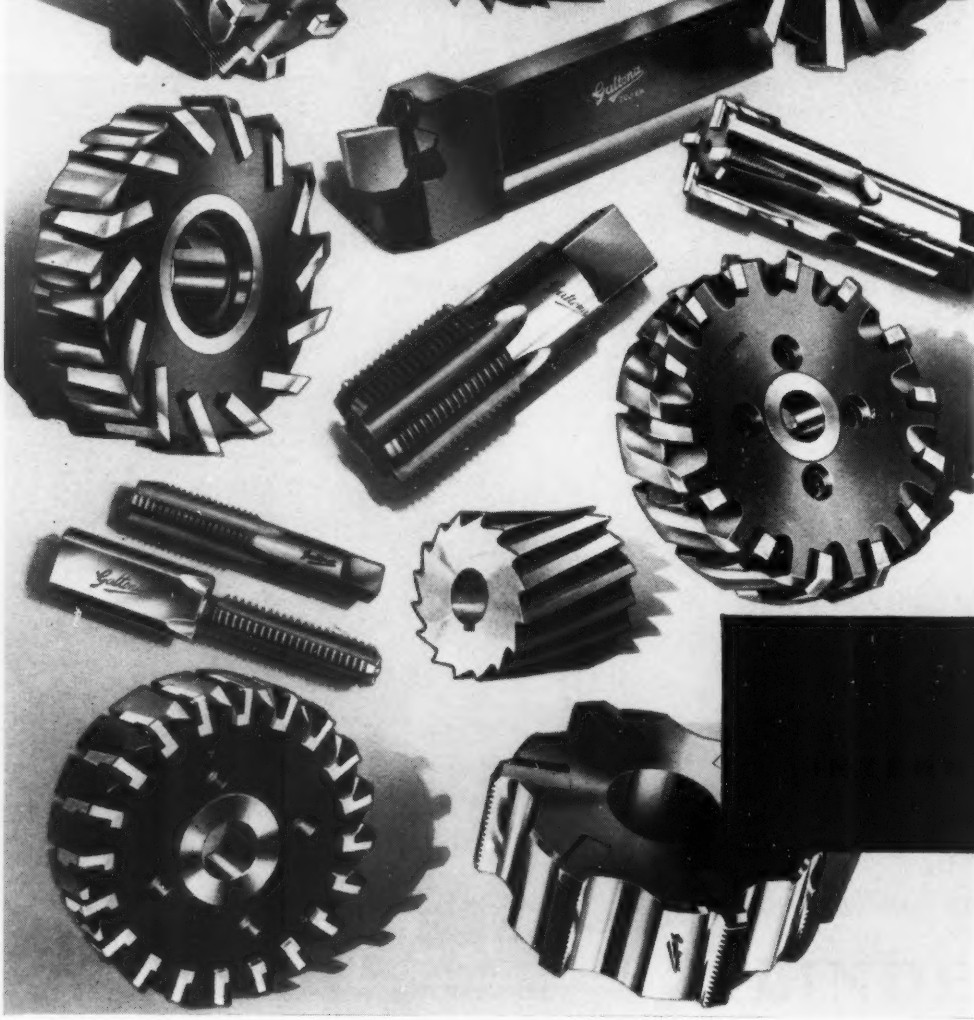

WICKMAN Erodomatic

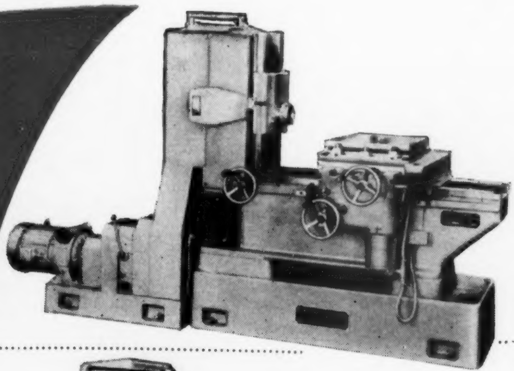

WICKMAN-SCRIVENER 24/30


WICKMAN 1¼"-6
Multi-Spindle Automatic


SNOW for
Rolls-Royce
Model "OS36/12" Precision Surface Grinders are chosen to assist in the production of Jet Engines.
STAND No. 23
INTERNATIONAL MACHINE TOOL EXHIBITION 1960
Olympia · London June 25–July 9
Photograph by courtesy of Rolls-Royce Limited
Model "OS" is available from 24" x 8" x 10" to 216" x 24" x 24".
SURFACE SNOW GRINDERS
SNOW & CO. LTD *Machine Tool Makers*
Stanley Street, Sheffield, 3. Telephone 22272.
DRUMMOND-ASQUITH LTD. *World Wide Distributors*
KING EDWARD HOUSE, NEW STREET, BIRMINGHAM. *Telephone Midland 3431. Also at LONDON, Telephone Trafalgar 7224 and GLASGOW, Telephone Central 0922,* EXPORT DIVISION: HALIFAX HOUSE, STRAND, W.C.2. *Telephone Trafalgar 7224.*

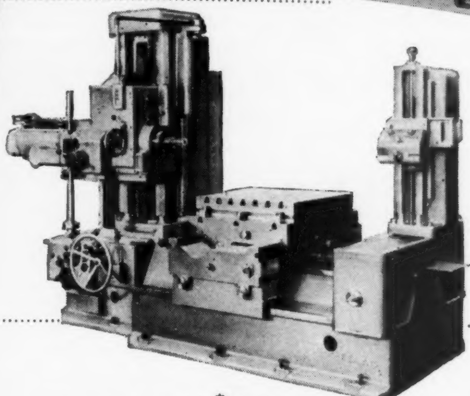
7


Galtona



'S' TYPE *OPTIMETRIC HIGH SPEED SPINDLE MODEL.

For a high degree of fine finishing, fitted with 2 h.p. motor giving infinitely variable speeds to spindle within the range 50-2,000 r.p.m.

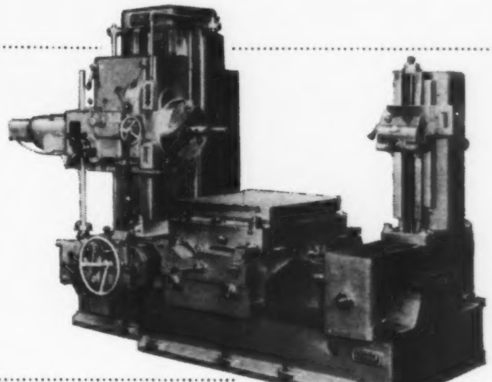


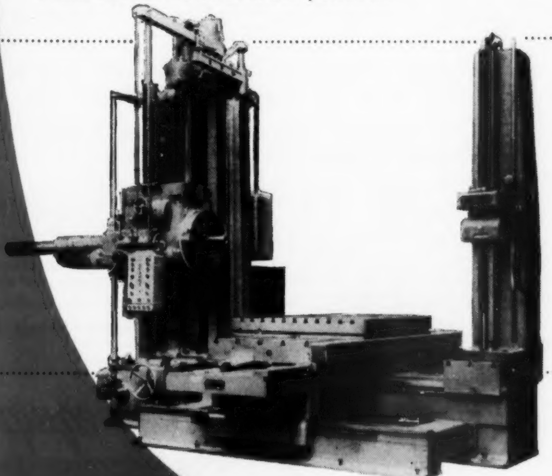
MODEL 450B *OPTIMETRIC HORIZONTAL TOOLROOM BORING MACHINE

Incorporates many patented features including projection type optical depth control to the main spindle.

MODEL 451P *OPTIMETRIC HORIZONTAL SURFACING, BORING, MILLING, DRILLING AND TAPPING MACHINE

An entirely new machine, with hydraulic tool clamping and release. Push button control from pendant.





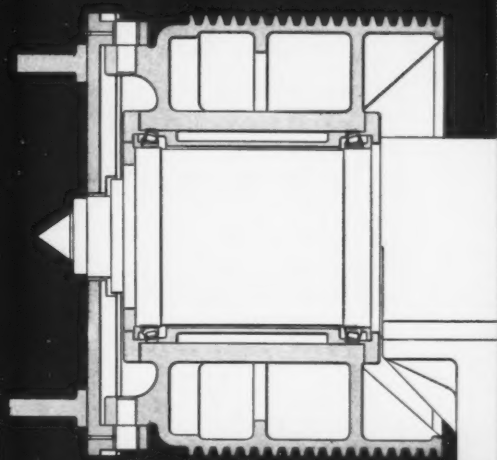
KEARNS No. 3WB PATENT ELECTRONIC UNIVERSAL HORIZONTAL SURFACING, BORING, MILLING, DRILLING, TAPPING AND SCREWCUTTING MACHINE

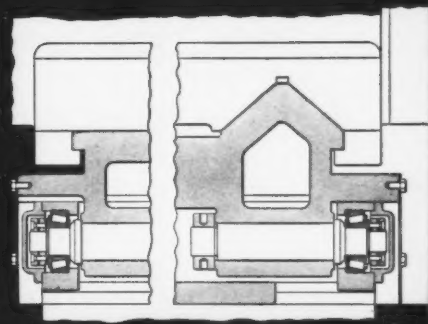
Accurate positioning with A.E.I. electronic co-ordinate setting to vertical and transverse movements by dials or punched card unit.

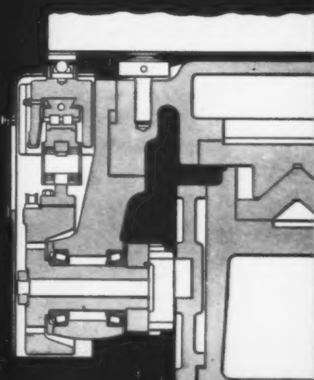
***OPTIMETRIC** is the registered trade mark of Kearns' system of optical measurement fitted as standard to all Kearns Horizontal Toolroom Boring Machines.

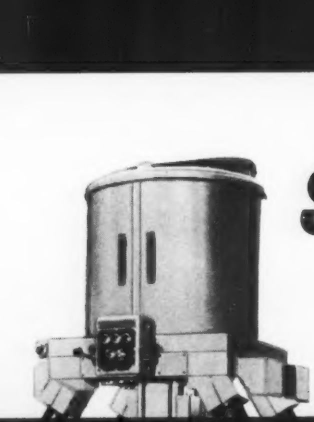
H. W. KEARNS & CO. LIMITED, Broadheath near Manchester

Telephone : ALTrincham 3284 Telegrams : "Kearns, Altrincham"

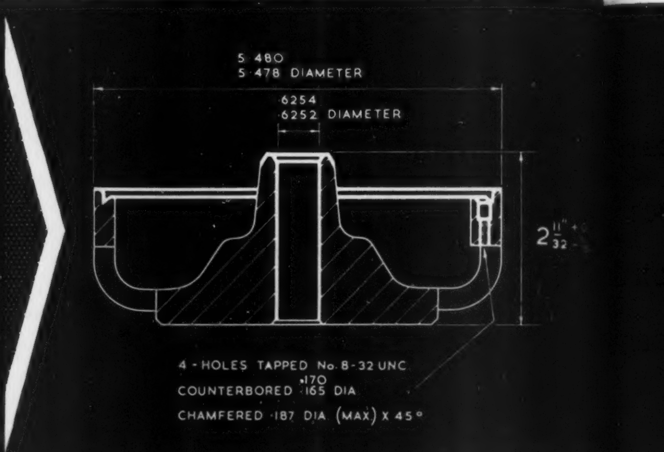








See how smoothly production



FROM THIS

See also No. 10 Verticalauto tooled for machining an Automobile Component

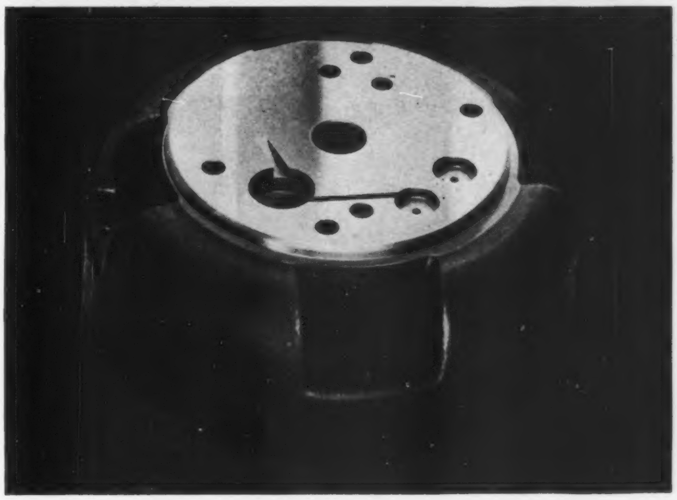
Ryder VERTICALAUTO

flows on Stand 28

INTERNATIONAL MACHINE TOOL EXHIBITION 1960

TO THIS

in 24 seconds



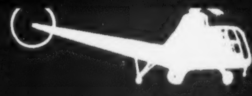
Two $\frac{1}{2}''$ dia. drilled holes
one $\frac{3}{4}''$ dia. drilled hole
six holes tapped
one $\frac{1}{4}''$ reamed hole
Two slots milled

Manufactured by
MULHEAD ENGINEERING Co. Ltd.

SOLE SELLING AGENTS:

Ryder

Thomas Ryder & Son Ltd.
Turner Bridge Works,
BOLTON, ENGLAND.

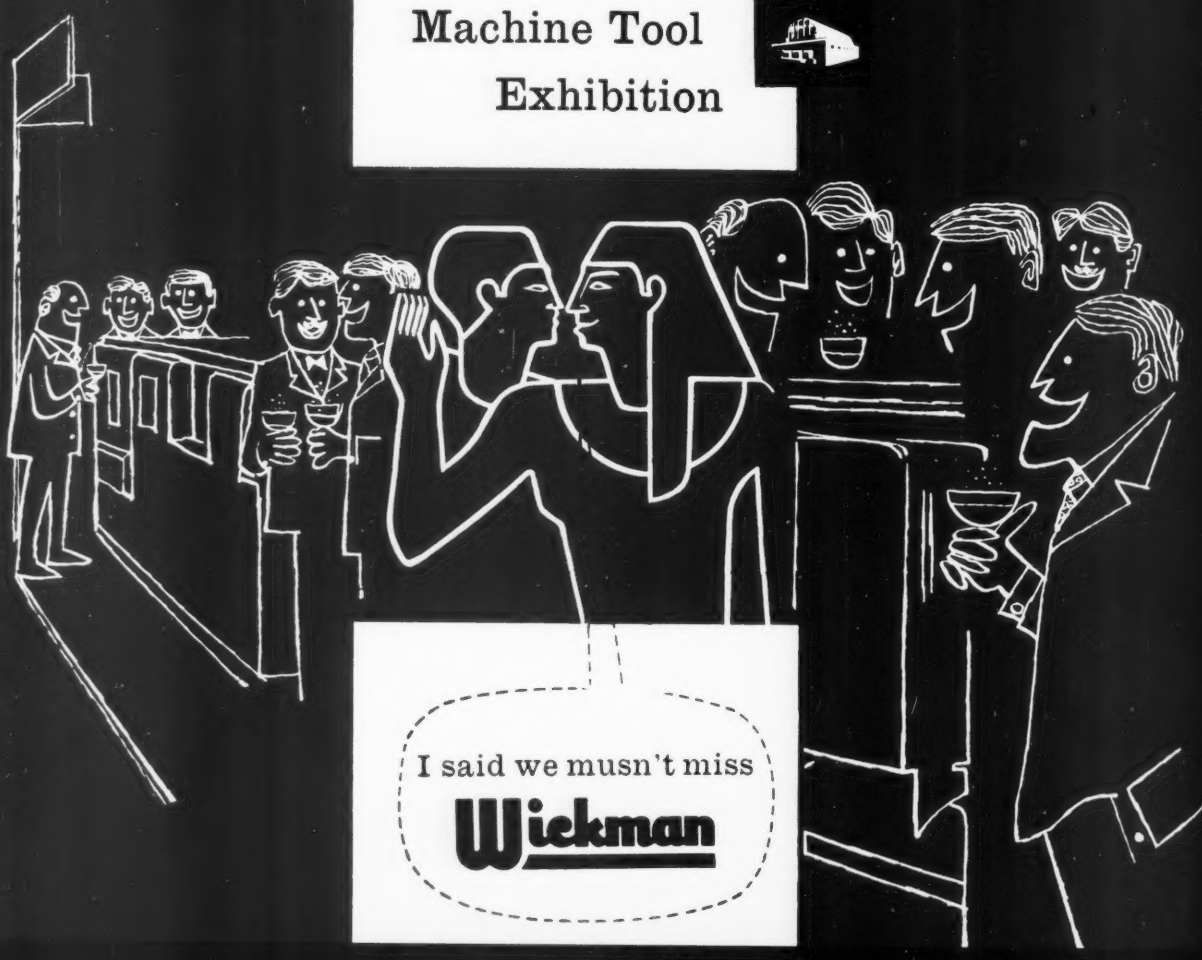


Direct helicopter flights from Wickman, Coventry to Olympia during the period of the show have been organised to assist industrialists in the Midlands who are especially hard pressed for time.

What are Wickman's up to?
Olympic Preview! In two short weeks from now we'll be looking for you at Olympia.
It's all laid on . . . Wickman style.
Full show of top machines.
Full attendance of boffins, demonstration-men . . . the lot.
Six scintillating stands, some a bit off the beaten track, but so well worth seeking out.

Wickman welcome all —

at the International Machine Tool Exhibition



The Production Engineer

THE JOURNAL OF THE INSTITUTION OF PRODUCTION ENGINEERS

VOL. 39 No. 6 JUNE, 1960

THE FUTURE TRENDS OF MACHINE TOOL DESIGN

A commentary by E. W. FIELD, O.B.E.,
President, Machine Tool Trades Association

TO look back over the past can be a pleasant, even if profitless, pastime. To look into the future, on the other hand, opens a wide field for speculation, forward planning and imagination. The last mentioned is not the least, for without it far-sighted planning is not possible and the risks inherent in speculation cannot be reduced to an acceptable minimum. The engineer, and particularly the machine tool maker, whose product is the root and branch of all industry involving the use of any kind of machinery, has a mind trained from the start to take cognisance of fact and yet to use his imagination. His is no wholesale and retail trade. He must sell his own product or do so through an agent who is himself a machine tool engineer. A high degree of efficiency is therefore essential, demanding intensive research into design and production methods on the one hand and into home and world markets on the other.

The machine tool builder, therefore, often looks into the past to remind himself of the causes of his failures and the steps which led to present improvements. He keeps a watch on present progress and, if he is to stay in business, a constant eye on the future.

It is a simple matter to describe in a few words the trend of demand since man first became a manufacturer by making things for others as well as himself. Industry, to use the word in its broadest sense, has continuously been asked to make more and more, faster and faster. This, concomitant with growing world population, will continue, since not only are there increasingly greater numbers of people to serve but they constantly strive for a higher standard of living. Greater purchasing power per head results in greater demand not only for the necessities of life but for the luxuries. These latter often become regarded as necessities as the standard of living rises. At the base of it all is the machine tool.

Faster and faster, more and more! The former means higher spindle speeds and feeds and in fact more rapid machine movements. There are limits. These are imposed by the nature and form of the material of the article in production. They are also imposed by the resistance to heat and vibration of the component parts of the machine. In these two directions then one may look for changes in the future design of machine tools. Means will be found for the effective dissipation of heat in the fast moving members of the machine.

Coupled with this will be changes in structure of machine tools with a view to minimising vibration and distortion. This will undoubtedly take the form of heavier main components, e.g., beds, headstocks and cross-slides, and work-tables.

It would seem that the past is not necessarily out of date and that there is truth in the assertion that "you can't beat solid cast iron!". On the other hand, as there is so often a Roland for an Oliver, a good deal of this same solid cast iron is used unnecessarily. Many items on a machine tool are now — and many more no doubt will be—replaced by injection moulded plastics. Such items include gear covers, gear train and belt guards, inspection covers, lever knobs, etc.

In the manufacture of machine units and in assembly one may look for a greater use of welding and automatic assembly. To mention welding in connection with the actual construction of a machine tool is perhaps to introduce a controversial subject, the pursuit of which, however, is not the object of this brief commentary. Certain it is that a great deal of the auxiliary equipment and attachments used in the grouping and automation of machine tools can involve welding processes to a considerable extent.

One has digressed a little from the speed of operation of the machine to its construction and assembly. To return then, speed of operation is, as already stated, subject to certain limitations. It is necessary, therefore, to look elsewhere for means of saving time

reducing idle time

in the process of production.

It is in the intermediate periods between one machining operation and another, between one machine and the next and in loading and unloading that the non-productive or idle times occur. The introduction of automation and transfer lines has reduced these idle periods to a remarkable degree, and it is in this direction that further developments may be expected.

In contemplating such developments, one is tempted to think of long unbroken lines of machines linking many operations in the production of a workpiece. Such a system could defeat its own ends, since even under the best conditions breakdowns occur. In the event, the entire line would be brought to a standstill. The answer then is comparatively short transfer lines. Emergency measures could be brought into action to by-pass a halted unit and to maintain the flow of production pending repair of the unit in question.

The terms "automation" and "transfer lines" are more often than not associated with large scale production, of which the motor car industry is, of course, the classical example. Other and much smaller sections of industry have their own problems. The production of small items or pieces of equipment, for all imaginable purposes, required in large quantities, is part of the daily life of many manufacturers having what might be described as a general engineering shop.

They suffer in the same way as would larger organisations if heed is not given to the loss of time in processing work from one operation to the next and from machine to machine.

An increasing number of such machine shops are improving their production by the introduction of automatic loading and unloading and the linking of standard type machines, thus establishing a valuable degree of automation.

In the operation of individual machines output is slowed down by manual changes of speed, feed, tool and work position changes. This has been speeded up by programme control. Application of such control has not yet been used to the maximum extent and new departures may be looked for in this direction.

All these pointers indicate the general direction which the design and construction of machine tools will undoubtedly follow. They are, however, more or less confined to their inherent possibilities for change in face and form. These have been in the past — and certainly will be in the future — influenced by the nature of the material on which they are to work. The introduction of high speed steel tools and, later, tungsten carbide tips resulted in major changes in machine tool design, particularly in the matter of speeds and feeds.

The machining of bar stock in the production of a piece having both large and small diameters can result in an enormous waste of time and material. Forgings have greatly reduced this wastage but if more time and material is to be saved, then obviously it will be necessary to "pre-form" the workpiece to allow for the very minimum of metal to be removed. This means more accurate castings and forgings. In this connection one has in mind, of course, metal cutting machine tools.

The efficiency of work produced by press formation obviously depends on the accuracy of the dies used. Clearly, to speed up output consistent with improved finish, changes in die manufacture are inevitable. Here again the nature of the metal under operation is a limiting factor in the extent to which the die can enhance production. The material itself must be made to assist in the process. Resistance to heat generation and distortion are essential qualities. Research into heat treatment and surface finish will undoubtedly be the precursor to developments in the structure of metals.

Automation or the virtually uninterrupted flow of a workpiece through a series of operations from machine to machine is obviously dependent for its efficiency on the speed and precision of the machines at the intermediate stages. Automatic sizing and compensatory devices are now standard features on many machine tools and their field of application will certainly extend.

elimination of inspection

It follows that such devices obviate the necessity for manual inspection and checking. The stage will be reached where inspection is virtually eliminated or, at least, where checking by electronic control can pick out undetected flaws.

A radical departure from normal methods of machining has been the use of ultrasonics, particularly in drilling operations. To use a more technically correct term, it should be described as impact grinding. The process is not employed with a view to speeding up production but to make possible those operations which hitherto have been regarded as practically impossible. The cutting and penetration of tungsten carbide, germanium, ceramics, etc., in fact

(*concluded on page* 387)

RECENT DEVELOPMENTS IN SPUR AND HELICAL GEARS

by C. TIMMS, D.Eng., M.I.Mech.E., M.I.Prod.E.

Head of Mechanisms, Metrology and Noise Control Division, National Engineering Laboratory.

AS implied in the title, the main object of the present Paper is to describe recent developments in spur and helical gearing, with particular reference to the requirements of the production engineer. In attempting to do this, it has been considered desirable to refer in some detail to other related aspects of the subject such as material combination, gear loading, performance, etc.

In common with other engineering problems, the need for improvement in accuracy and manufacturing techniques inevitably arises from the results of field experience, which provides the necessary stimulus and incentive for basic and applied research. The history of marine propulsion gears over the past 25 years is a typical example of this approach in which the failure of gears under normal conditions of service from tooth breakage, pitting, scuffing and excessive noise, was rightly attributed in the first instance to inaccuracies in gear cutting, lack of temperature control and inadequate machine foundations. Although there were other ancillary causes of gear failure, the results of the initial investigations carried out during the late War indicated the vital necessity for a comprehensive research and development programme. On the other hand, in computer and control systems the basic requirement is for the gears to mesh with minimum backlash, and that gear trains should operate smoothly and in some applications with uniform velocity. To meet these requirements, a refinement in both measuring techniques and manufacturing process has been necessary in recent years.

In some industrial applications, the quality and performance of gear units leaves much to be desired and the failure of many gears in service can be attributed to insufficient knowledge of the basic elements of gear geometry, inadequate design facilities and lack of suitable measuring equipment. A typical example is the unsatisfactory standard of accuracy in change gears supplied with some standard machine tools.

* Presented to The Institution of Production Engineers in Glasgow, 17th March, 1959.

standard specifications

Since 1945, considerable effort has been devoted to the preparation and revision of standard specifications for gears of all types, including gear cutting machines and associated cutting tools. This work is regarded as being of primary importance both to the manufacturers and users in the United Kingdom and also in the expansion of our export trade, especially in European countries. In common with other British standards, they are widely used by technical colleges, providing valuable information on basic design and accuracy requirements which is not available in a concise form in well-known text books on the subject.

The need for new British standards for gears has arisen in the first instance from the requirements of the service departments, although in the subsequent preparation of the actual specifications all branches of the industry have freely contributed to this work. There is, however, a need for combining many of the existing specifications. On spur and helical gears there are at present four separate specifications covering fine pitch gear units, traction and automobile drives and marine installations. Much of the information on basic tooth proportions, tolerances and load rating is common to all of these gear applications and one comprehensive standard would avoid unnecessary duplication and difficulty in interpretation which occurs at the present time.

In the international field, British specifications have been used as the basis for international specifications and although the work is still in the preliminary stages, considerable progress has been made to date. In this connection, it is of interest to mention that B.S. 1498 for gear hobbing machines is used by most countries for final acceptance tests on these machines.

gear measurement

The overall quality and performance of any gear initially depends on the accuracy of the gear blank, and it has often been said that a gear can only be as accurate as the blank from which it has been

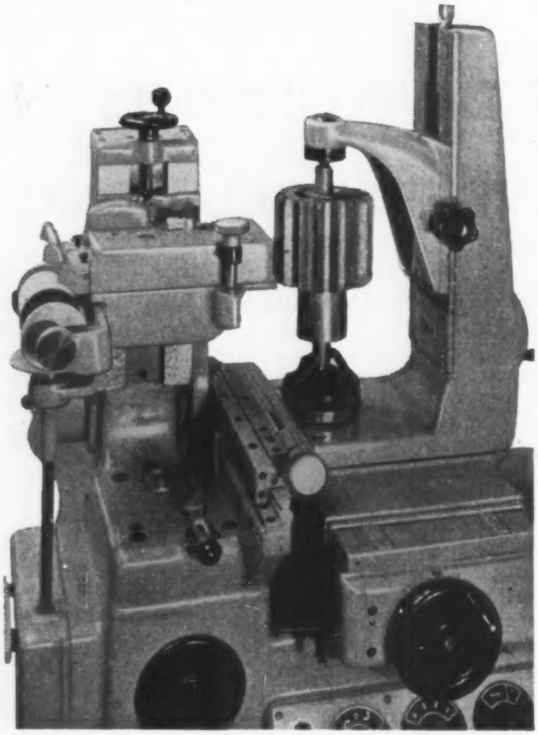


Fig. 1.

made. Whilst this statement is an undisputed fact, the problems associated with design and gear cutting techniques often overshadow the importance of these preliminary machine operations. Many faults in gear performance originate from lack of attention to the machining of suitable radial and axial locating surfaces on the blank.

The conventional approach to gear inspection can be broadly divided into two parts :-

1. the examination of the individual gear tooth elements; and
2. composite tests, dual or single flank.

For gears up to about 20 in. diameter, it is more convenient to mount the gear direct on the measuring instrument, but for larger diameters the opposite approach is preferred in which a portable type of instrument is applied to the gear. The former design is undoubtedly more costly than its portable counterpart, but its greater ease of operation and freedom from personal manipulation results in a higher standard of accuracy.

measurement of small and medium size gears

For the measurement of tooth profile errors, an instrument employing the well-known base disc principle, in which the errors in form are directly related to a disc of the appropriate base circle diameter, is the one which is widely used. This approach to the problem has that unique property of simplicity in geometrical concept, and the basic kinematic design provides means for obtaining the highest standard of accuracy. The manufacture of individual base discs for works inspection is sometimes regarded as an unnecessary refinement and many firms prefer the adjustable design of instrument incorporating a master base disc, by means of which it is possible to generate any involute within the machine capacity. The additional linkage mechanism required for this purpose is, however, a further source of inaccuracy as wear of the bearings and pivots can affect the truth of the generating process.

The main improvement in recent years in involute measuring instruments has been the use of electrical recording units in place of mechanical indicators or mechanical chart recorders. The former have a higher speed of response and a wider range of magnification, but their greater cost is an obvious disadvantage. Experience shows that there is a need for closer co-operation between mechanical and electronic firms on the design of a compact form of recording unit which is tailor-made to suit a specific application. It is unfortunate, but nevertheless true, that instrument firms in Western Europe adopt a more realistic approach to design details of this nature and appear to have a better appreciation of users' requirements. This is certainly the case on many gear measuring instruments. Under the most favourable conditions of instrument operation, departures from the nominal involute form cannot be determined to an accuracy of better than 0.0001 in. This limitation is not generally appreciated by designers or inspection staff when specifying departures from the nominal form. In addition, for pitches finer than about 40 D.P., it is necessary to resort to optical techniques which limit, still further, the overall accuracy of measurement.

In some designs, provision is made for the measurement of both the tooth profile and helix angle and the Maag PH.60 machine, illustrated in Fig. 1, is a good example of this arrangement. This is widely used throughout Great Britain and although it was first introduced to this country shortly after the late War, there is still no British equivalent. Present British practice appears to favour the development of single-purpose instruments for both profile and lead measurement and the Orcut lead measuring machine, Fig. 2, is a typical example of a single-purpose design. It is of robust construction, capable of a high standard of repeatability and accuracy, and is widely used by many inspection departments. The lead generating mechanism is of mechanical design, incorporating the well-established sine-bar principle for angular control. In Continental designs similar to the PH.60, it is customary to use a precision circular scale and microscope for this purpose. There is, however, little to choose between these two techniques from an accuracy point of view, but the optical design is more compact and generally more suitable for instrumental applications.

The selection of a vertical or horizontal axial instrument is also a point of some importance. In

general, the vertical design provides a better load distribution on the head-stock bearing and it also facilitates setting up, especially when inspecting internal gears.

For the measurement of circular pitch errors, including short spans and overall cumulative errors, there is a definite shortage of suitable commercial equipment. The present practice of adopting standard types of circular dividing tables or precision polygon used in association with an auto collimator only provides a partial solution to this problem. One limiting factor of a fundamental nature is the accuracy of angular reference standards, which at the present time cannot be specified finer than ± 1 sec. of arc. This uncertainty in angular measure is equivalent to the pitch tolerances for many precision indexing gears. From the practical point of view, difficulties also arise with direct angular methods of measurement when inspecting gears with prime numbers of teeth. The method of test is a slow and exacting procedure involving manual operation of the measuring equipment, which tends to affect the accuracy of measurement due to operator fatigue. This is particularly the case when measuring gears with more than 100 teeth, as the time required for the complete inspection can amount to several hours.

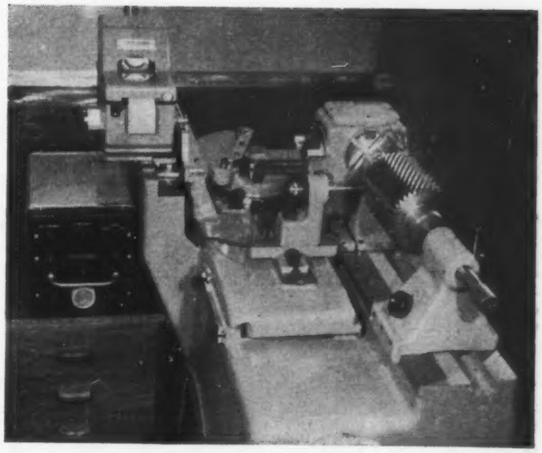


Fig. 2

Fig. 3

Fig. 4.

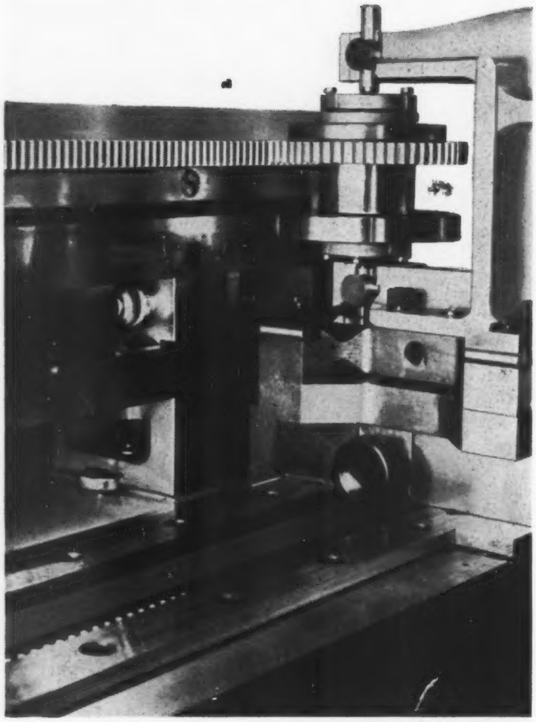


Fig. 6

Appreciation of these difficulties at N.E.L. led to the development of an automatic indexing instrument illustrated in Fig. 3; it is completely automatic in operation and the variations in tooth spacing are registered directly on a chart recorder. With this instrument, the time required for inspection is about one-fifth of that required for manual inspection methods. Equipment based on the N.E.L. design has been developed commercially by The Coventry Gauge and Tool Co. and by The Sigma Instrument Co., and Fig. 4 shows the general arrangement of the instrument manufactured by The Sigma Co. It incorporates a multi-pen recorder for measuring tooth thickness variations and variations in tooth alignment in addition to pitch measurement. It has the same high standard of performance as the N.E.L. prototype mentioned above and is considered to be one of the most advanced instruments of its type in the world.

composite tests

Although the direct measurement of gear tooth elements is the fundamental approach to gear metrology, providing the information necessary to establish a rational tolerance system, the detailed inspection involved is not always suitable for general routine inspections. For general works use, it has been the practice for many years to use the dual flank composite test, of which the Parkson type of tester is a well-known example. In recent years, it has been used extensively for the control of gear manufacture on a production basis where minimum backlash is an important design requirement, and also in the more general case where a definite amount of backlash is not only permissible but essential. Fig. 5 shows the smaller size of instrument manufactured commercially by Messrs. J. Goulder & Sons. It incorporates a number of refinements to facilitate inspection and improve accuracy which are not provided in the original design.

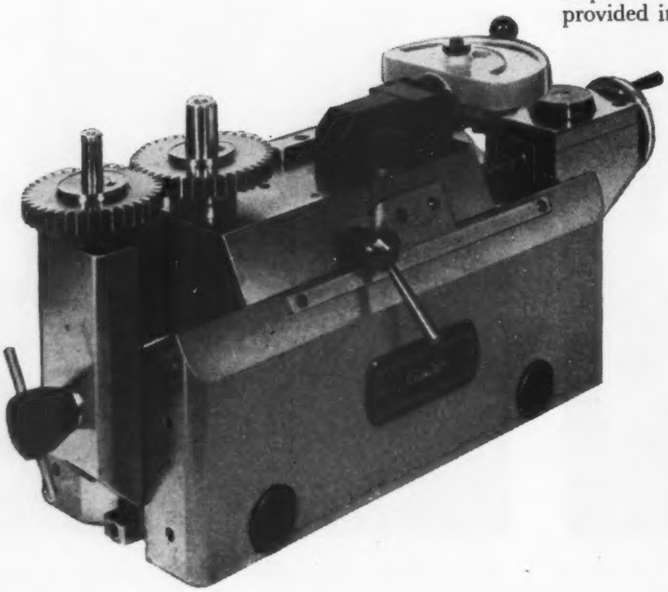
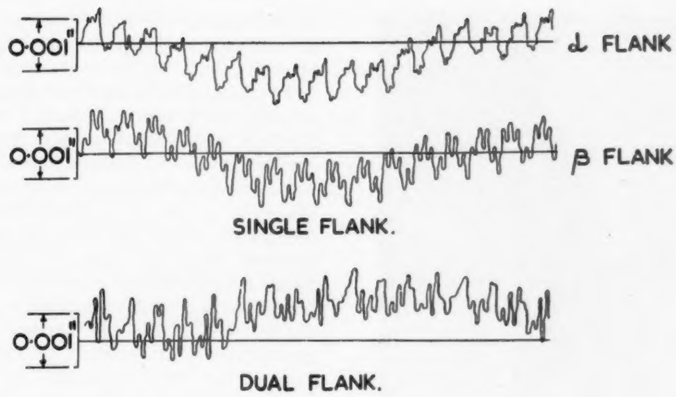


Fig. 5



RACK MACHINE TYPICAL TEST RESULTS.

Fig. 7.

In those applications where angular motion of the input and output shaft of a gear drive requires to be accurately maintained during all phases of relative movement, a more refined inspection procedure is required and one approach to this problem is to measure the composite errors of each set of flanks separately. This has been achieved at N.E.L. by using a master rack instead of a cylindrical master gear and Fig. 6 shows a general view of the prototype instrument[1]. The curves in Fig. 7 represent the results of both single and dual flank measurement from the same production gear. These curves illustrate quite clearly the difficulties which can arise when the dual flank test is the only method of production control. This point is not generally appreciated, but as mentioned above it is an important factor in indexing systems. This statement is in no way an adverse reflection on the usefulness of the dual flank instrument but the point has been made in order to draw attention to this matter, especially the attention of those who tend to regard it as the answer to all gear inspection problems.

measurement of large gears

The need for improvement in the accuracy of large gears, especially those used in marine reduction drives, arose initially from the requirements of the British Admiralty and also Lloyds Register of Shipping. These two departments were largely responsible for initiating at the National Physical Laboratory an extensive research programme to investigate the causes of failure in this type of gear drive. The original work carried out at the N.P.L., and later at N.E.L., has been responsible for a considerable improvement in gear accuracy over the past 20 years and many of the instruments developed in these laboratories now form standard equipment in most engineering departments, both in this country and abroad. Unfortunately the advantages to be gained from this basic work have not been followed up by British instrument manufacturers and many refinements in recording technique, which could have been readily applied, have been left to firms abroad to develop.

The numerous cases of gear failure which occurred during the late War have been fully reported elsewhere[2]. At that time filing of the pinion teeth to improve tooth contact was the accepted practice of the day and this, apart from other reasons, indicated that the standard of gear cutting was far from satisfactory. A further point of some significance was the lack of any organised system of measurement and the design and development of suitable equipment was regarded by the Admiralty as one of the most urgent requirements. The major part of the research programme on basic instrumentation was carried out in the Metrology Division of the N.P.L. during the period 1939 - 46 and the results of this work showed at an early date some of the primary causes of gear failure[3]. There was a need for a radical change in machine tool design, in which the basic mechanism had been changed little from that suggested by Sir Charles Parsons some 30 years earlier. In addition, the facilities available in marine engine firms for gear cutting left much to be desired.

A complete range of portable instruments has been developed for measuring errors in the teeth of marine gears. The form of instrumentation used was largely dictated by the physical dimensions of the main reduction wheel (Fig. 8) and also the practical difficulties in attempting to relate the tooth errors to the gear axis. In reviewing the instruments developed to date, there is no doubt that the gear tooth undulation recorder originated by Tomlinson in 1939 has been of the greatest value to the manufacturers and users of gear hobbing machines. The results obtained with this instrument substantiated the earlier evidence derived from visual inspection of gear sets, and formed the basis for the subsequent theory of gear tooth undulations. Analysis of the initial recordings showed that periodic errors in gear

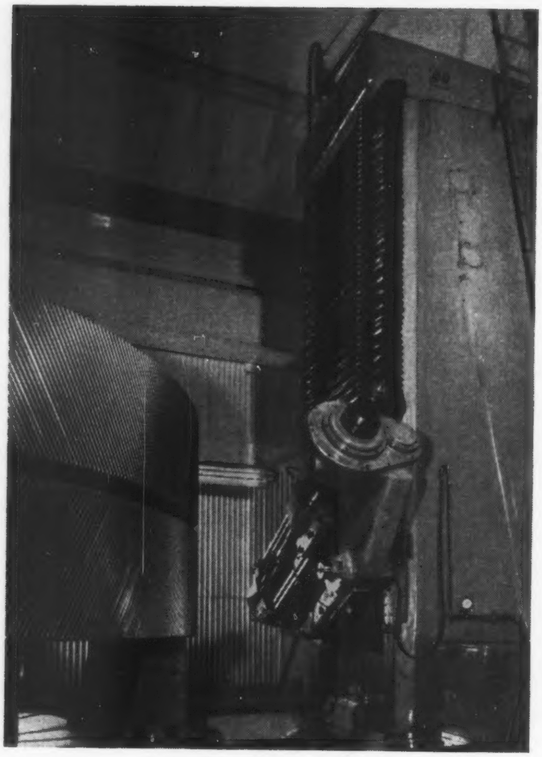


Fig. 8.

hobbing machines was one of the primary causes of unsatisfactory gear cutting, and this work was largely responsible for the prolonged technical discussions which followed on the merits of "creep" versus "non-creep" machines, including the most appropriate creep fraction to use.

It is of interest to mention that the results of undulation recordings taken over the past 18 years show a reduction in total amplitude from 0.01 in. to within 0.0005 in. for hob-cut gears, which reflects the great improvement in gear cutting accuracy achieved over this period of time. The improvement in finish achieved has, however, necessitated changes in instrument design in order to record undulations of less than 0.0002 in. in total amplitude.

In parallel with the investigation on surface undulations, work was proceeding on the most suitable method of measuring the circular tooth spacing errors. In view of the limitations of direct methods of angular measurement mentioned earlier, it was necessary to use an indirect method of approach by measuring the variations between successive spans of teeth. Pitch comparators for this purpose can be broadly divided into two distinct types : flank-to-flank measurement, and measurements over tooth-space-centre-lines. With the former, it is customary to establish radial and axial reference surfaces for location of the comparator on the gear under test as recommended in B.S. 1807. The provision of suitable reference on production gears is still regarded by many manufacturers as being of secondary importance to the actual process of gear cutting, but greater care in this direction would facilitate the work of the inspecting department. With the centre-line type of pitch gauge no datum surfaces are required, and the relative simplicity of this design of comparator and its ease of manipulation offset many of the advantages claimed for the flank-to-flank gauge. There are, however, a number of weaknesses common to each type of comparator; some are of a fundamental nature associated with the process of span measurement, whilst others arise from manual operation in which the results vary according to the degree of skill and experience of the operator.

The results of pitch measurements taken over the past few years show that the requirements of B.S. 1807 in respect of the maximum cumulative pitch error and the adjacent pitch error can now be largely achieved. The main difficulty arises from errors over short spans of teeth, which originate from errors in the master wormwheel correcting machines.

A problem of equal importance on helical gears is the control of the tooth lead. This has been one of the most difficult of the measuring problems encountered to date. Various types of instrument have been developed, both in this country and abroad, but none provides a completely satisfactory solution. Of these, the N.P.L. design of axial pitch

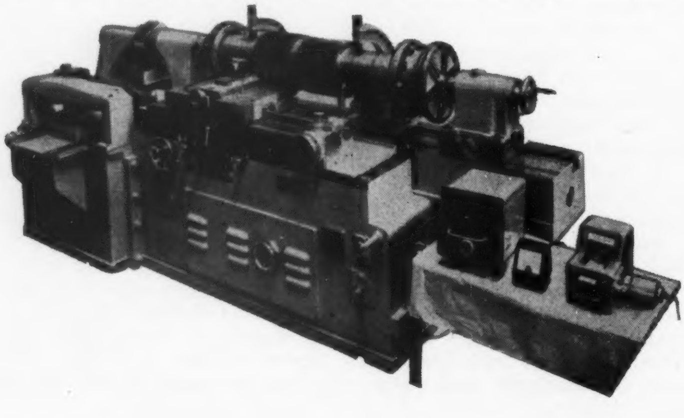


Fig. 9.

gauge is by far the most successful. It requires a high degree of manipulative skill, but under favourable conditions of operation an accuracy of measurement to the order of 0.0001 - 0.0002 in., over a nominal length of 6 in., can be achieved. In view of these difficulties, and also the need for precise information on the helix correction to be applied to marine gear pinions, a lead measuring machine was designed and manufactured under the guidance of the Admiralty Vickers Gearing Research Association. Fig. 9 shows a general view of the machine; it has a diametral and length capacity of 20 in. and 70 in. respectively. Measurements are made relative to the journals on which the gear rotates and departures of the helix from its nominal lead are recorded autographically to an accuracy of within 0.0001 in.

With the introduction of post hobbing processes, there has been an increasing emphasis on the need for closer control of tooth form, which has led to the development of a number of different types of profile recorder. In some instruments, advantage is taken of the fact that on large gears the departures of the profile from a straight datum line are comparatively small; these departures are amplified and then compared with the nominal form. In other types of instrument, measurements are made of chordal thickness at specified positions down the tooth and compared with the corresponding calculated nominal values. The overall accuracy of each system of measurement is not considered to be better than about 0.0002 in. and in view of the length of time required for measurement, they are not suitable for general inspection use.

gear cutting machines

(a) large gear hobbing machines

The most significant developments in the design and accuracy of gear cutting machines during the past 20 years have occurred in the field of large gear hobbing machines. As previously mentioned, the initial programme of research commenced at N.P.L. in 1939 which led to the formation in 1946 of the Admiralty Vickers Gearing Research Association (A.V.G.R.A.). This Association, operating under the

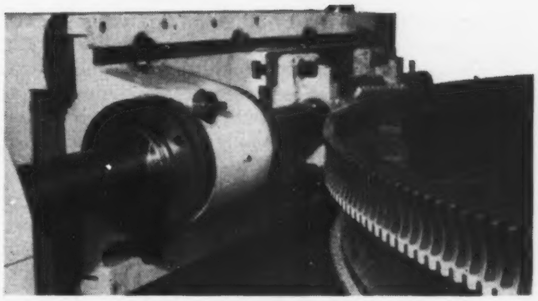


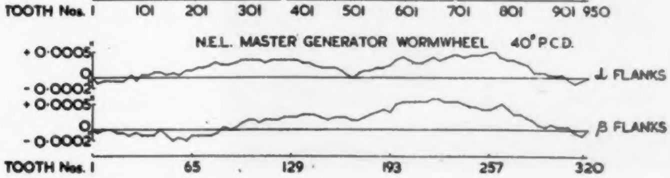
Fig. 10.

direction of the Admiralty, carried out an extensive survey of gear cutting facilities in the member firms of the Association. The results of this work provided valuable information on existing facilities and formed the basis for specifying future requirements on machine design, finishing processes, foundations, temperature control, accuracy, etc.

It is also important to mention the work carried out by other firms and establishments in the United Kingdom[4, 5, 6] who, prior to the formation of A.V.G.R.A., had made considerable progress in gear accuracy by appreciating at an early date the benefits to be gained from N.P.L. research. The need for a comprehensive standard of accuracy for gear hobbing machines was initially suggested by Lloyds Register of Shipping and the first meeting of the appropriate British Standards Committee was held in 1944. Although these facts are now historical, they represent important milestones in the development of this work and the main points arising from all of these developments are briefly summarised below.

(i) *Machine Kinematics* — the ratio of all gear pairs between the hob and table drive requires careful consideration. A high ratio for all gear pairs immediately adjacent to the main indexing worm and hob spindle is essential in order to minimise the effect of periodic

Fig. 11.



errors on the tooth finish of production gears. These gear pairs should preferably be of the spur or helical type. In addition, the theoretical wave lengths of periodic errors should be as short as possible, so that full advantage can be taken of the overlapping effects of successive hob cuts and also of post hobbing processes.

(ii) *Table Drive* — the resultant accuracy of any mechanism inevitably depends on the number of connecting links and a direct worm and wormwheel drive appears to be the best practical compromise. The advantages claimed for the "creep" mechanism must be set against the practical difficulties of producing an accurate internal gear.

(iii) *Temperature Control* — the dissipation of the heat generated by the machine requires careful consideration at the design stage. The variation in column alignment which occurs during the initial running of a machine is a classic example. Diurnal changes in the air temperature in the gear machine room should not exceed $\pm 1°F$. A temperature variation of only $\pm 1°F$ can produce undulations of 0.0002 in. in depth on a gear 12 ft. in diameter.

(iv) *Machine Foundations* — much depends on the nature of the sub-soil and the location of heavy machinery in the immediate vicinity of the proposed site. Opinions differ[7] on the suitability of concrete and steel structures, although in each case isolation from the sub-foundation is important. In the past, it has been the practice to use cork or felt as the damping medium but experience shows that a rubber mat is more effective in reducing vibrations of low frequency.

(v) *Main Machine Driving Elements* — adequate commercial facilities are now available for the manufacture of lead screws and indexing worms for the attainment of Grade A requirements of B.S. 1498. The manufacture of dividing worm wheels to the same grade of accuracy still presents a problem. In recent years, strenuous efforts have been made by two manufacturers of large gear hobbing machines to overcome this difficult problem by developing master wormwheel generating machines. In view of the national importance of this project, some Government financial support was provided although the major cost of the overall development was in fact borne by each firm. The two machines are similar in basic design and one of them is illustrated in Fig. 10. Pitch measurements of two master wormwheels cut on one of these machines are shown by the curves in Fig. 11. It is of interest to mention that the initial proposal for the development of such a machine on a national basis was first recommended in 1944, but it was almost 10 years before actual commercial action was taken.

The design of a further master gear generating machine of smaller capacity has been carried out at N.E.L. This machine, illustrated in Fig. 12, was manufactured by David Brown Industries Ltd., and the pitch measurement of its dividing wormwheel is shown by the curves in Fig. 11. This machine is now being installed in the Metrology Division of N.E.L., and its function is to provide British industry with the highest quality of master wheels comparable with the facilities which have been available for many years for the measurement and correction of lead screws.

Fig. 12.

TABLE I

Machines examined by N.P.L. from 1941 - 46

(Unit 0.0001 in.)

Number of Machines Examined and Test Period	Machine Cyclic Errors		
	Worm Frequency	Hob Frequency	Feed-screw Frequency
	Average Value	Average Value	Average Value
36 machines. 1941 - 3 (Pre-1939 design)	22	21	6_5
24 machines. 1945 - 6 (New and reconditioned machines)	7	4	5

TABLE II

Machines and Test Gears examined by N.E.L. since 1955 in accordance with B.S. 1498: 1954, Grade A

(Unit 0.0001 in)

Type, Capacity and Number of Machines Examined		Machine Cyclic Errors						Spur Test Gears					Helical Test Gears
		Worm Frequency		Hob Frequency		Feed-screw Frequency		Pitch Errors					Undulations Total Depth
								Max. Cumulative		Short-span		Adjacent	
		Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	
Pinion 24-60 inches 5	Measured values	2_5	1-3_5	2	0_5-4	2	0_5-4	11	5-17	4_5	2_5-6_5	1	Within 2
	Grade A values	3		4		4			8_5-24		4_5-6_5	3-3_5	2_5-3
Wheel 50-100 inches 8	Measured values	2	1-4	1	0_5-2_5	1_5	0_5-3_5	13	8-22	5	2-8_5	1	Within 2
	Grade A values	3		4		4			17-41		4_5-8	3-3_5	2_5-3
Wheel 150-216 inches 11	Measured values	2	0_5-4_5	1_5	0_5-2_5	1_5	0_5-2_5	29	10-42	7	3-11_5	1_5	Within 2
	Grade A values	3		4		4			27-49		4_5-8_5	3_5	3_5-4_5

(vi) *Overall Machine Accuracy* — the results in Table I show the accuracy of machines examined by N.P.L. during the period 1941 - 1946 and those in Table II machines of modern design examined by N.E.L. since 1955. A comparison of the results given in Tables I and II clearly shows the marked improvement in accuracy over the past 15 years.

Referring to Table II, the following points are of interest :-

(a) The machine cyclic errors do not vary with the size of machine; in fact the measured values tend to be greater on pinion machines.

(b) As would be expected, the maximum cumulative pitch error increases with machine capacity, but in all cases it is within the Grade A value.

(c) Short span pitch errors exceed the Grade A values on machines of the largest capacity.

(d) Adjacent pitch errors do not vary with machine diameter and in all cases are well within the Grade A values. This may arise from the fact that machines of modern design have master wheels of relatively fine pitch.

(e) In association with (a) above, the amplitude of the undulations appears to be independent of machine capacity, although the effect of diurnal temperature change is necessarily more marked on the larger machines.

(f) The results of the conventional machine alignment tests have not been included in Table II. Grade A limits can be attained in the majority of cases although adjustment to slides and bearings is often required.

(g) Twenty-one of the 24 machines mentioned in Table II are of British manufacture, of which 18 were produced by one firm.

(h) All machines, with one exception, are of the solid table design; the odd one out incorporates the "true creep" mechanism.

(b) small gear hobbing machines

There have been no marked improvements in the accuracy of standard commercial gear hobbing machines for cutting small and medium gears and in many instances the general standard of accuracy leaves much to be desired. In some fields where the highest precision is essential, as in fire control equipment and servo systems, some effort has been made to meet user requirements, but on a very limited scale. The recently published British Standard Specification 3013 for small precision gear hobbing machines should focus attention on this problem and provide the necessary stimulus to machine tool manufacturers in this country. It would indeed be unfortunate if we had to revert to our pre-War practice of depending on foreign sources of supply for machines of the highest precision.

Some important advances have been made in increased rates of hobbing for large scale production using gear shaving as the finishing process. This type of production is used in the automobile industry where the cost of automatic control of manufacture and inspection is fully justified.

(c) gear shaping

The gear shaping process using rack and circular type cutters is widely used for the manufacture of spur and helical gears, especially cluster gears and internal gears. The basic design of each type of machine has shown little change over the past 20 years and in the case of the rack type machine, improvements in accuracy have been largely confined to machines manufactured abroad. The need for improvement in accuracy and machine maintenance was revealed by the results of an extensive survey of gear accuracy carried out at N.E.L. for the Admiralty. The results of this investigation revealed the fundamental weakness of the shaping process in regard to large local errors in adjacent pitch, commonly referred to in the trade as "tooth drop".

(d) gear grinding

The process of gear grinding can be broadly subdivided as follows :-

1. Formed wheel grinding in which the form of the grinding wheel corresponds to that of the finished gear.
2. Generating grinding in which the form of the grinding wheel corresponds to the basic rack tooth shape.

For gears up to about 3 ft. in diameter, the accuracy attainable by each process is substantially the same. This was confirmed by Laboratory examination of two helical gears, one produced by the generating process in Switzerland and the other by the formed wheel process in England. In regard to machine performance and repeatability, there is little to choose between each method and in each case a great deal depends on the skill and experience of the machine operator.

The commercial development of gear grinding machines in the United Kingdom has largely concentrated on the formed wheel principle, although for fine pitch gears a modified form of generating grinding has been introduced on a limited scale in recent years. For machines of capacity exceeding 3 ft. in diameter, the United Kingdom is entirely dependent on foreign sources of supply. This unsatisfactory state of affairs is well-known to those responsible for the design and manufacture of hardened and ground gears for marine installation and similar drives, but effective action has not extended far beyond committee deliberations. In view of the national importance of this project, there is undoubtedly a need for Government financial assistance to promote active commercial development in this field.

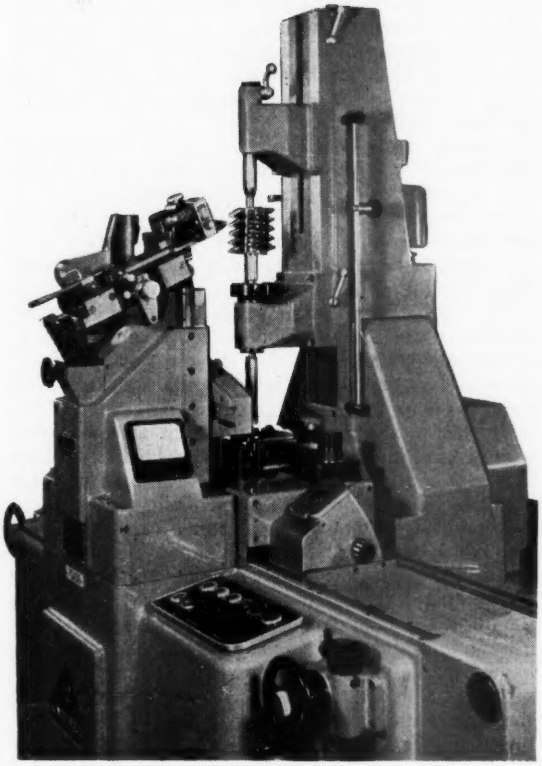


Fig. 13.

gear cutting tools

In recent years considerable attention has been given to the standardisation of grades of accuracy, overall dimensions, pitch range and tooth proportions of gear cutting tools, and the scope of this work is reflected in new and revised British Standard specifications. One of the many problems has been universal acceptance of a common basic rack for all gears and although there is general agreement throughout most branches of the gear industry to this proposal, there are several notable exceptions, especially in marine and instrument applications.

For the majority of applications, involute gears, derived from the basic rack having a depth of $\frac{2}{DP}$ and a flank angle of 20°, are widely used with highly satisfactory results. In certain instrument applications, however, especially in the fine pitch range where a high step-up ratio is required thus necessitating pinions with small numbers of teeth, the cycloidal form is preferred [8]. It is extensively used in the watch and clockmaking industry and has advantages over the involute system where minimum tooth friction and smoothness of tooth action are essential. On the other hand, in many marine drives using through-hardened gears, an increase in tooth

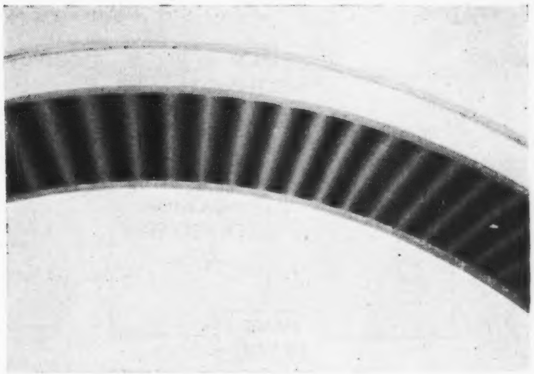


Fig. 14.

depth over that provided by the British Standard form is required, and in such cases it is customary to use a flank angle of 16°.

The measurements of the tooth elements of circular and rack type gear cutters and shaving cutters is basically identical to spur and helical gearing, and the same inspection equipment can therefore be employed.

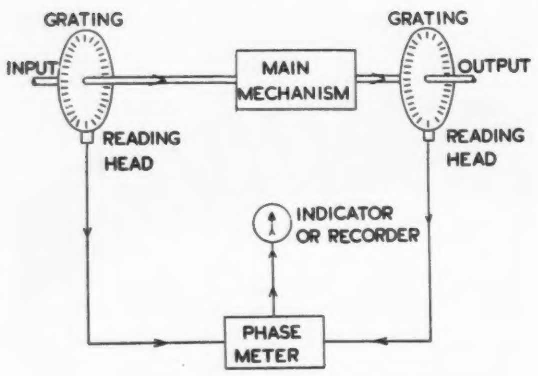
With regard to hob inspection, the usual British practice is to control by independent inspection methods the linear pitch of the hob flanks and form of the cutting edges. This approach is satisfactory for single start hobs, but presents difficulty on multi-start and wormwheel hobs due to the greater curvature of the cutting edges.

The firm of J. Goulder & Sons has recently introduced a novel design of instrument for the measurement of the linear pitch of hobs. It provides a continuous measurement of the individual flank errors which are recorded autographically, and it represents a marked improvement over existing methods of measurement.

In Western Europe, direct measurement of the errors in base pitch is favoured since with mating R.H. and L.H. hobs equality of base pitch is the primary factor. The instrument illustrated in Fig. 13 was initially developed for this purpose, although in its present form it now incorporates many additional features for hob inspection, including facilities for linear pitch measurement.

application of gratings to measurement and machine control

In preceding sections of this Paper, considerable emphasis has been laid on the measurement, and the more difficult process of correction, of errors in gear cutting machinery. The attainment of the present high standard of accuracy has been dependent in no small measure on the mechanical skill of a few experienced craftsmen. This painstaking work, often carried out in unfavourable workshop conditions compared with accepted standards, offers no guarantee that the ultimate accuracy will in fact be achieved or maintained when the machine is



TYPICAL MEASURING SYSTEM.

Fig. 15.

installed on its permanent site. In addition, there is evidence to show that further improvement in machine accuracy is limited by the accuracy of existing measuring techniques, and refinement of these traditional systems of measurement will only provide a partial solution to this problem.

Considerable attention has therefore been given to this problem both at N.P.L. and N.E.L. in recent years, by the development and application of diffraction gratings to engineering metrology and machine tool control. In view of the importance of this original work, it is considered that some reference to its development and application to machine tools is appropriate.

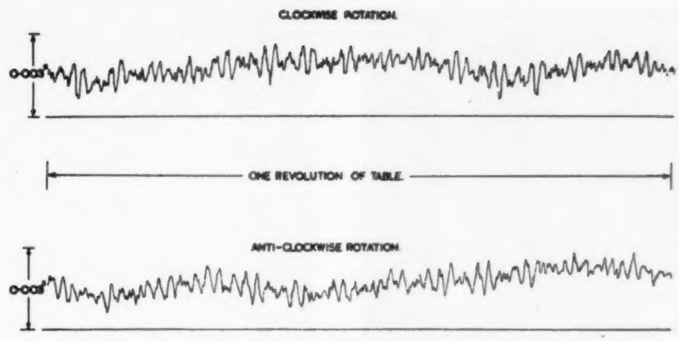
The production of relatively inexpensive linear gratings by a process developed at the N.P.L.[9] precipitated their application to measurement and control in the field of mechanical engineering. It was also realised at an early stage that applications to rotary motions would demand gratings of high angular precision and the production of radial gratings was, therefore, developed at N.E.L. Improvements in grating production techniques [10] have been pursued at both establishments and today a wide range of both linear and radial gratings is available for many applications.

Fig. 16.

Gratings are essentially glass scales with a high line density and in order to read these scales, resort has to be made to an optical phenomena called the moiré fringe effect [11]. For example, if two gratings are placed in close proximity face to face and illuminated, there is produced a pattern of fringes, shown in Fig. 14, which moves through one fringe pitch when one grating moves through one line pitch relative to the other. A photo-electric cell is used to detect the passage of the fringes and gives an electrical output which is sinusoidal in form and cyclic with respect to the pitch of the gratings. The main advantage in using gratings as measuring scales is that information can be extracted from them in a near-continuous flow, and thus form the basis for dynamic measurement and subsequent control.

Measuring systems using gratings can be divided into two groups, digital and analogue. Digital systems use increments of displacement equal to the pitch or a fraction of the pitch of the gratings and process the information electrically in circuits similar to those used in digital counters and computers. Such systems have been applied mainly to programmed control of milling machine tools [12]. Analogue systems, on the other hand, subdivide the grating pitch using the phase of the electrical signals as the analogue of displacement, and hence discrimination comparable with the digital system can be achieved with relatively coarse pitch gratings and simple optics.

A typical analogue system [13] is shown in Fig. 15 applied to the measurement of errors from designed constant displacement ratio of a mechanism. It consists of two gratings, one attached to the input member and one to the output member, the ratio of the pitches being the same as the displacement ratio of the mechanism under test. Reading heads associated with the gratings produce, when the mechanism is running, sinusoidal signals of the same frequency. Errors in the mechanism give rise to phase shifts between signals which are detected in a phase meter, the resultant error signal being indicated or recorded. This system can be applied to mechanisms which have a designed constant displacement ratio and whose input and output motions are either rotary or linear. Fig. 16, for example, shows a gear hobbing machine with one system applied to the measurement of errors between the rotation of the table and the rotation of the hob spindle, and a second system measuring the errors between the linear traverse of the hob saddle and the rotation of the feed screw. The chart record in Fig. 17 shows the errors between the hob and machine table over one complete revolution of the latter. It reveals, in addition to cyclic errors of hob and worm frequency, the complete range of pitch errors in the machine master wheel. This new process of measurement has many advantages over the conventional smoked plate technique, since in addition to providing a complete



RELATIVE ERRORS BETWEEN HOB SPINDLE AND MACHINE TABLE.

Fig. 17.

picture of all machine errors between the two elements, the actual recording takes only a matter of a few minutes to carry out.

Another application is shown in Fig. 18 by the measurement of rotational errors in a gear pair. It provides a new and novel approach to single flank measurement of a production gear in relation to a master gear. The same principle can be applied with equal facility to the measurement of wormwheels, bevel gears, universal joints, etc., since there is no restriction on centre distance or orientation of the shafts carrying the gears and gratings.

An extension of the measuring system is to feed back the error signal to correct the mechanism. A schematic diagram of a correcting system is shown in Fig. 19 and a photograph of an experimental set-up is shown in Fig. 20. It comprises a measuring system as before, but the error signal from the phase meter is fed to a servo amplifier and motor. This injects continuously small correcting displacements into the mechanism through a differential in such a way as to reduce the errors. Fig. 21 shows records taken from the experimental equipment with and without correction. A comparison of these two curves clearly shows the considerable improvement in accuracy which can be achieved without recourse to any mechanical adjustment or correction. One obvious application of this technique is to the control of the final table drive in a gear hobbing machine and work on this project is well advanced. In principle, it can be applied to any size of machine and offers a completely new approach to the measurement and correction of machine tool errors.

A somewhat different analogue technique has been applied to the automatic measurement of precision lead screws. Equipment suitable for the examination of screws up to 18 ft. in length is illustrated in Fig. 22. This type of measurement using conventional static techniques would take several hours to complete, but with the present automatic system the

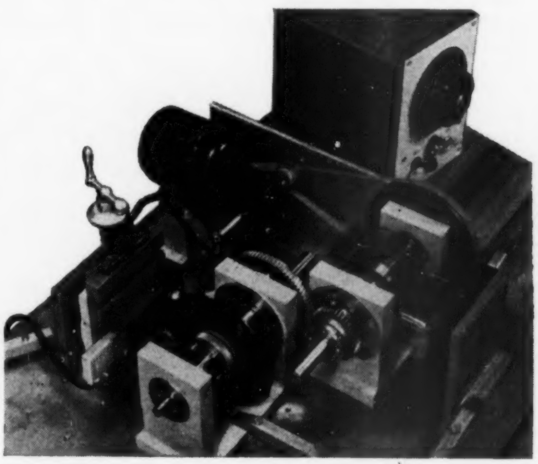
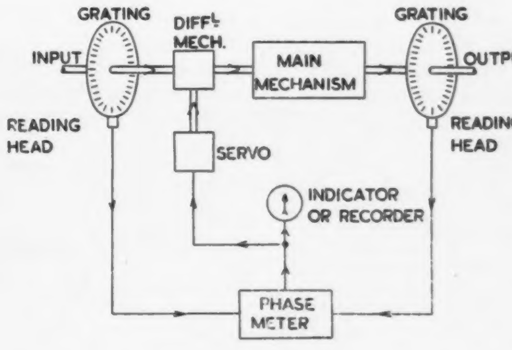


Fig. 18.



TYPICAL CORRECTION SYSTEM.

Fig. 19.

Fig. 20

whole process is carried out in almost as many minutes.

Gratings have formed the basis of the developments described above, primarily because of their availability, but parallel developments have taken place both in this country and abroad [14, 15]. It is, however, regarded as a matter of national importance that the commercial application of precision gratings to measurement and machine control be carried out with the minimum of delay. This type of work calls for the closest co-operation between Government departments, instrument industry and the manufacturers and users of machine tools.

gear performance

Improvements in the loading of marine gears, both at home and abroad, have been reported in considerable detail in Papers presented to the International Conference on Gearing held at the Institution of Mechanical Engineers in 1958. Research on marine gears in the United Kingdom has been carried out by two sister organisations, A.V.G.R.A. and P.A.M.E.T.R.A.D.A., in collaboration with the Admiralty. Broadly, the research work carried out by A.V.G.R.A. has been concerned with machine tools, cutting processes, heat treatment, and material testing, whilst P.A.M.E.T.R.A.D.A. has largely concentrated on gear design and full scale gear testing [16, 17].

These researches have shown the advantages to be gained from hardened and ground gears, especially for naval vessels where an increase in loading of four-and-a-half times over previously accepted standards is reported. For marine applications a more conservative increase in loading is necessary, due to the marked difference in machinery operation between merchant and naval vessels, and also to the fact that the incentive to save weight and space is not so great. In addition, existing methods for grinding large helical gears are not at present an economic proposition for merchant vessels and with greatly improved facilities for hobbing and shaving which are now available in most marine firms, this position is not expected to change in the next decade.

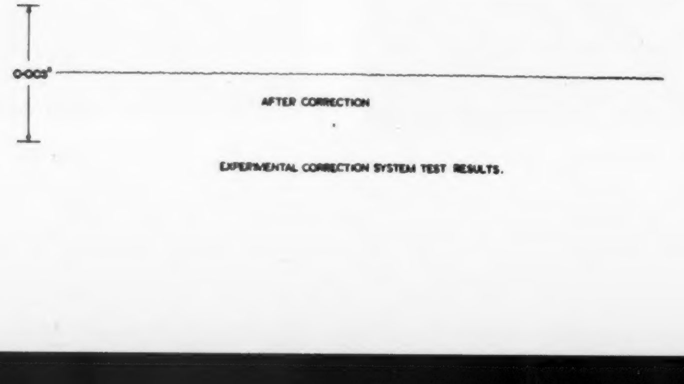


Fig. 21

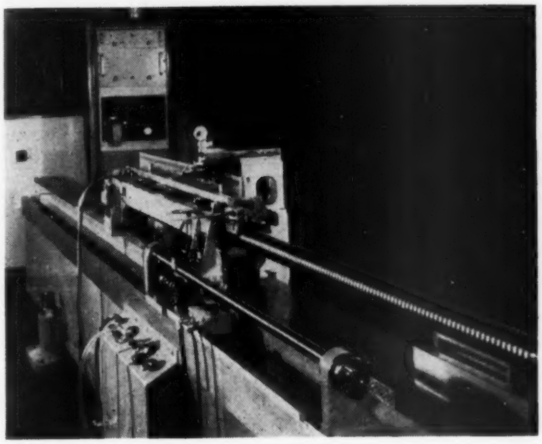


Fig. 22.

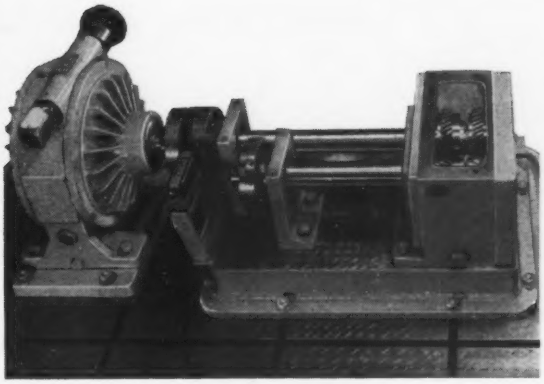


Fig. 23.

Similar improvements in gear durability have been reported at the above mentioned Conference for automobile and aircraft transmissions,[18] although the results achieved were not so spectacular as in the marine field. There was little mention, however, of gear performance in the general commercial field and therefore a reference to work carried out at N.E.L. should be of interest, as it is more closely related to the basic design requirements given in B.S. 436 : 1940.

The main objectives of the N.E.L. gear research programme are to determine the effect of dimensional errors and peripheral speed on load carrying capacity, and to investigate the compatibility of different gear materials with specific reference to surface deterioration.

Details of Test Gears

The essential gear details are given below :-

Normal Pressure Angle ...	20°
Helix Angle	25½°
Normal Diametral Pitch ...	10
Working Depth	$\frac{2}{DP}$
Face Width	0.8 in.
Axial Pitch	0.729 in.
Gear Ratio	$\frac{27}{38}$
Centre Distance	3.6 in.
Material Combination ...	En.8 (wheel) En.9 (pinion)

The gears were tested in a conventional type of back-to-back rig (Fig. 23), and comprise two pairs of identical test gears attached to separate pairs of solid and hollow shafts. Torque is applied to the system when the gears are stationary by means of a lever arm and dead-weights through a flanged coupling. The drive consists of a 7½ H.P. motor and variable speed unit connected to the other end of the system *via* a flexible coupling. The gears are classified by the method of finishing and are broadly divided into three groups, commercial hobbing, precision hobbing and shaving. The average standard of dimensional accuracy for each finishing process is illustrated by the curves in Fig. 24 and the average percentage contact marking is indicated below :-

Commercial hobbing	50%
Precision hobbing	56%
Shaving	80%

The number of tests carried out for each process was :-

Commercial hobbing ...	32 pairs of gears
Precision hobbing	24 pairs of gears
Shaving	68 pairs of gears

criterion of surface failure

A direct comparison of the results of gear tests carried out by different research establishments and by individual firms is almost impossible, due to the fact that there is no accepted criterion of what constitutes surface failure both for pitting and scuffing. With regard to surface failure by pitting, a great deal depends on the type of application and in many instances the appearance of one or two localised pits would not be regarded as sufficiently serious to justify replacement, yet this course of action would be required on aero engine transmissions. Even in the more restricted field of actual gear research, there is no accepted terminology between one department

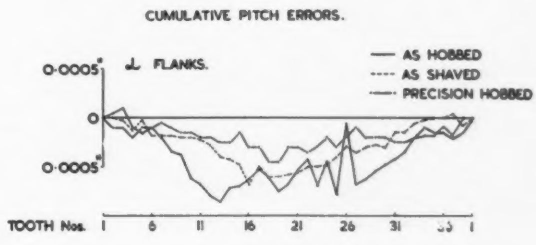


Fig. 24a.

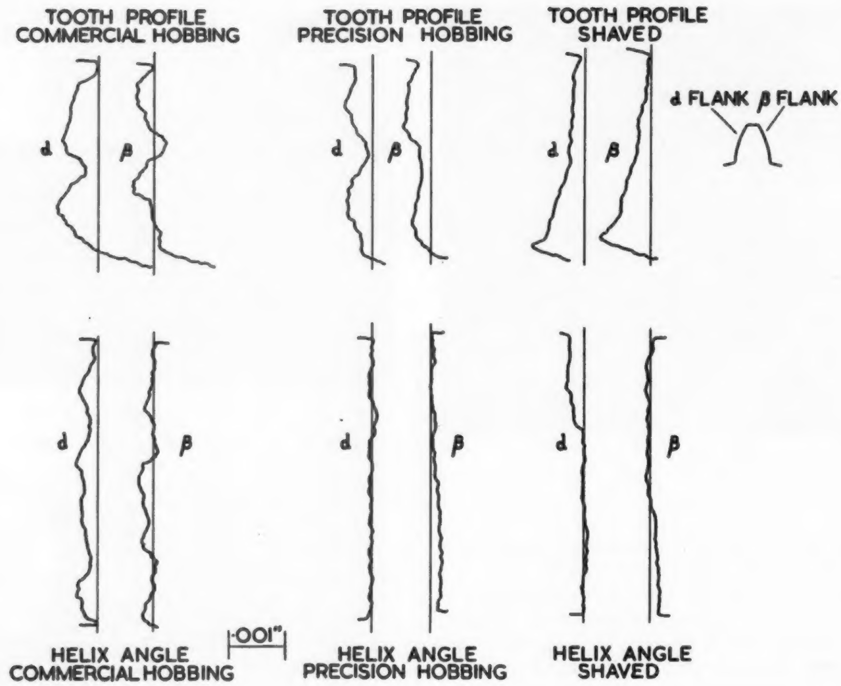


Fig. 24b.

and another, rendering inter-comparison of the results obtained in related fields extremely difficult, if not impossible. There is undoubtedly a need for co-ordination in this work and the setting up of a gear information centre is worthy of consideration. It will avoid overlapping of research interests and at the best provide a rational basis for the assessment of research results.

In view of the many different methods used for assessing surface damage, an explanation of the method used is desirable. In this investigation, the method selected was to disregard pits smaller in surface area than about 1 sq. mm. and to count all the rest as being indicative of surface damage. The appearance of the first four pits was taken to signify material failure, provided the pits were evenly distributed around the teeth of the gear. Material failure does not imply gear failure, but complete failure was likely to occur if the tests continued under the same conditions of speed and load. This arbitrarily selected criterion proved to be reliable in that all gears tested, which satisfied the material failure condition, showed a clear tendency to continue pitting with increasing number of load cycles.

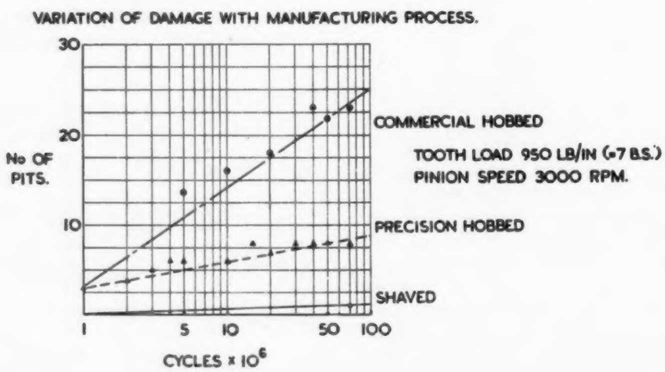


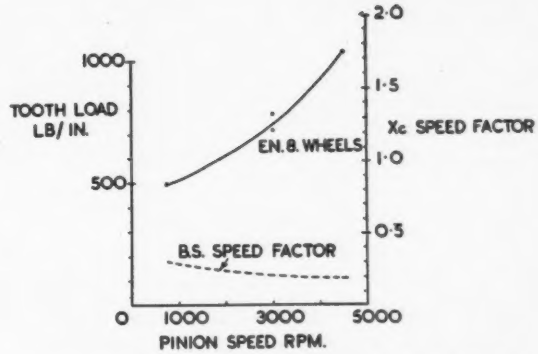
Fig. 25.

The curves in Fig. 25 are representative of each of the finishing processes used. They clearly show the relationship between pitting resistance and dimensional accuracy. In these tests the gears were run at a constant speed of 3,000 rev./min. with a normal load of 950lb./in. which is equivalent to seven times B.S. rating assuming a speed factor of 0.23. These results are typical examples of a large number of tests and confirm that for a given material combination, the load rating in terms of the surface stress factor is related to the dimensional accuracy of the gears. This subject is not covered in British Standard specifications for gears and there is urgent need for information on the allowable load for a specific grade of accuracy.

speed effect

A further series of tests was carried out to determine the effect of speed on load carrying capacity. Sets of gears of equivalent dimensional accuracy and finished by shaving were run at speeds of 750, 3,000 and 4,500 rev./min. and in each case for a length of time corresponding to 40 million load cycles. For each speed, the maximum load which could be carried without material failure was determined and is shown by the full line curve in Fig. 26. These values have been derived from tests on 68 pairs of shaved gears. The slope of this curve indicates that the safe load carrying capacity of a gear pair increases with speed and at a speed of 4,500 rev./min. the load rating is approximately twice that at 750 rev./min. A similar trend has been observed on gears finished by hobbing and suggests that the effect of dynamic loading arising from pitch errors is either negligible, or is counteracted by other factors which tend to increase the allowable load with increase in speed. These results are quite contrary to established practice based on British Standard specifications for speed factor in which the appropriate curve is reproduced in Fig. 26. Similar observations have been noted by other investigators [16, 19]; for example, in marine drives the secondary reduction gears usually show signs of failure earlier than the first reduction gears. It is possible that with improvements in pitch accuracy, effect of dynamic loading will be less marked and on precision gears it represents a small proportion of the nominal load. There is, however, ample practical evidence to show that uneven distribution of the load due to unsatisfactory meshing is a major cause of gear failure in service.

It is of interest to mention that in practically all cases pitting commenced in a region immediately below the pitch circle of engagement, there being little evidence of pitting in the addendum of each gear. The pits appeared to commence at the surface of the material and of the large number of specimens examined, there was no case which indicated sub-surface failure. It would appear that the direction of sliding in association with the lubricant could account for the location of the pitted areas, but results obtained from disc tests also carried out at N.E.L. do not confirm these observations. The testing machine used for this purpose is shown in Fig. 27 and consists of two 8 in. diameter discs and one 4 in.



DURATION OF TESTS - 40 MILLION CYCLES OF WHEEL

SHAVED GEARS - EFFECT OF SPEED ON LOAD CARRYING CAPACITY.

Fig. 26.

diameter disc in En.8 and En.9 materials. These results showed that provided the finish and dimensional accuracy of the disc surfaces were of a high standard, surface failure by pitting did not occur, but the material tended to collapse with excessive load, i.e., in the region of three-and-a-half times the British Standard rating. Attempts to correlate the results from gear and disc tests have not proved successful to date.

gear efficiency

Precise information on the efficiency of gear transmissions is not readily available and in view of this, details are given of tests carried out on a speed reducing unit [20] comprising a set of spur gears 8 D.P., centre distance 8 in., ratio 3 : 5. The tests were carried out with dip and spray lubrication, using a mineral oil having a supply temperature of 60°C and

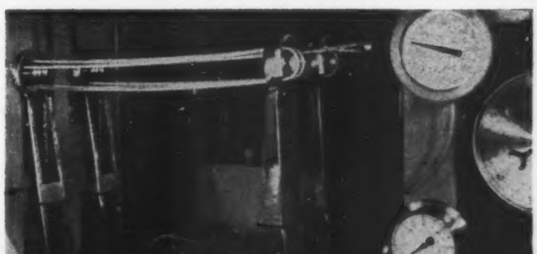


Fig. 27.

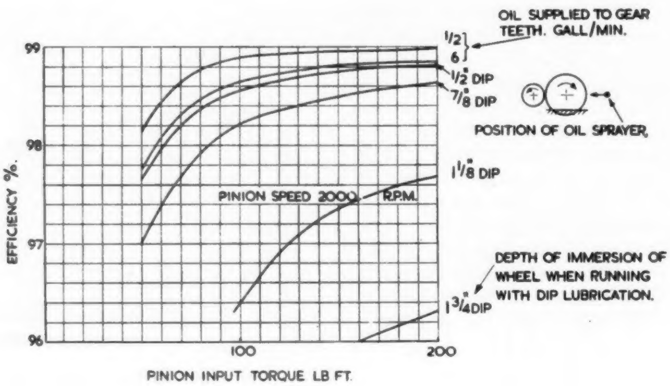


Fig. 28.

a viscosity of about 60 centistokes. The results of these tests are shown by the curves in Fig. 28 and the results are summarised below:

(i) At full speed and load the total torque loss with normal spray lubrication is about 1% and approximately half of this is due to bearing losses.

(ii) A change in the rate of sprayed oil from ½ to 6 gal./min. did not appreciably affect the overall efficiency. The higher rate represents about eight times the normal recommended value.

(iii) The losses are greatest when oil is sprayed into the engaging side of the mesh and the increase in loss can amount to 0.5% of full load torque. When used as a speed increasing gear, there was no measurable change in the losses. It should, however, be noted that the existing ratio is only 6 : 10 and changes may occur with higher ratios.

(iv) Dip lubrication with normal immersion depths does not cause losses differing substantially from those occurring from spray lubrication.

(v) There is, however, a marked increase in loss with excessive depths of immersion. The direction of rotation is also important when using dip lubrication and it can account for an additional loss of about 2%.

gear noise

Available information on the causes of gear noise is of a very general nature and there are only a number of very brief references to the subject [21] in the recent International Conference on Gearing. It is generally agreed that with improvement in dimensional accuracy there has been a reduction in overall noise level, but there is no specific information on the actual causes of gear noise or what is regarded as an acceptable standard. The subject is, however, attracting the attention of many users and there is no doubt that more searching tests will be demanded for future requirements.

In association with the present research on load capacity, a series of noise tests was carried out on hobbed and shaved gears [22] and the results are shown by the curves in Fig. 29, in which the spread of each set of measurements is indicated by the shaded areas. The general noise level of the power circulating machine is also shown from a test in which the test gears were replaced by rubber rollers. These results are of interest, as they reveal that the noise level at tooth contact frequency is substantially the same for hobbed and shaved gears, although there are marked differences in profile and adjacent pitch accuracies (Fig. 24). This fact has been noted by other research workers and it appears that at tooth contact frequency the noise level is not necessarily dependent on gear accuracy. The main difference in noise level occurs in the region of twice tooth contact frequency and in the case of the hobbed gears, this dominant frequency could be due to the inferior quality of the hobbed tooth profiles, in which the characteristic wave form of the profile graph is indicative of excessive hob eccentricity or cyclic error of the cutting edges. A more critical noise investigation of the shaved gears also revealed marked evidence of both frequencies and at higher speeds the higher frequency content of the noise became clearly important. In these gears the profile measurement showed no obvious trace of a double flank wave pattern similar to the hobbed profiles, and the actual cause of the higher frequency content is at present unknown.

From these brief observations it will be clear that the subject of gear noise demands a more critical examination than hitherto, in order to assess the factors influencing noise generation and to provide guidance on methods for noise suppression. On the more fundamental side, there is ample scope for basic research on the noise generated by mating pairs of discs operating under conditions of pure rolling and with varying degrees of sliding. There is also evidence to show that the damping effect of different material combinations has a marked effect on noise and further work in this direction is desirable.

future developments

In reviewing the field of work covered by this Paper, the following points merit some consideration :

(i) The United Kingdom is still dependent on foreign sources of supply for instruments of the highest precision.

(ii) There is a need for closer co-ordination between the gear industry and the instrument manufacturers. Many of the firms manufacturing inspection equipment have limited or, indeed, no facilities for the development of optical and electronic techniques so important in present-day requirements.

(iii) The manufacture of gear instrumentation in the United Kingdom is carried out on a piecemeal basis. It is regarded as a sideline by too many firms and in view of this there is no counterpart to well-established and well-known firms abroad.

(iv) The basic work initiated at N.P.L. and N.E.L. on the production of accurate linear and radial diffraction gratings has provided a new approach to engineering measurement and machine control. It is to be hoped that machine tool firms and instrument manufacturers will take full advantage of this work.

(v) There is a need for improvement in the accuracy of gear cutting machines in the small and medium size range.

(vi) Production capacity for the grinding of spur and helical gears above 3 ft. in diameter is limited to machines of foreign manufacture.

(vii) The manufacture of marine type gear cases still presents a problem. This subject is not specifically referred to in the present Paper.

(viii) The setting up of a gear information centre is worthy of some consideration. One of its objects would be to collate the results of gear research in progress in all establishments.

(ix) Further research is required to establish design data suitable for general use and for the revision of the loading formulae specified in B.S.436.

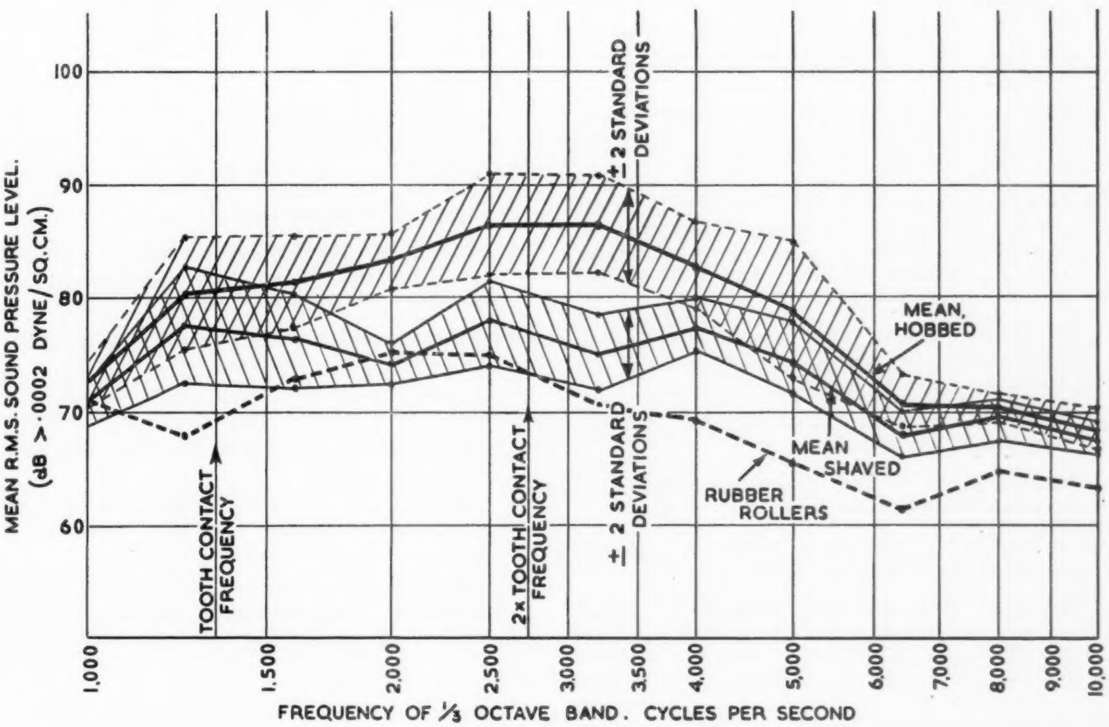


Fig. 29.

(x) The subject of gear noise has not been seriously considered in the United Kingdom, although considerable research has been carried out elsewhere, particularly in the U.S.A. The general problem of noise is receiving increasing attention in both the technical and daily press, and a technical appraisal of gear noise in particular is considered to be timely.

acknowledgments

The author gratefully acknowledges the assistance received from numerous firms and also the members of his staff who have been closely associated with this research.

The Paper is published by permission of the Director of the National Engineering Laboratory.

REFERENCES

1. TIMMS, C., and HUNTER, O. R. " Master Rack Gear Tester." *Metalworking Production*, 30th December, 1959. Pages 2,099 - 2,102.
2. JOUGHIN, J. H. 1951. Proceedings. Institution of Mechanical Engineers, London. Volume 164, page 157. " Naval Gearing — War Experience and Present Development."
3. TIMMS, C. 1947. Proceedings. Institution of Mechanical Engineers, London. Volume 157, page 418. " Measurement of Errors in Turbine Gears."
4. DAVIS, A. W. 1945. Transactions. Institution of Engineers and Shipbuilders in Scotland. March. Volume 88, page 179. " Current Practice in Marine Gear Cutting."
5. SYKES, A. 1947. Proceedings. Institution of Mechanical Engineers, London. Volume 157, page 405. " Progress in Turbine Gear Manufacture in Recent Years."
6. DOREY, S. F., and FORSYTH, G. H. 1947. Transactions. North-East Coast Institution of Engineers and Shipbuilders. Volume 63, page 267. " Some Gear Cutting Inaccuracies and Their Effect on Gear Loads and Gear Noises."
7. BRADDYLL, J. R. G. 1958. Proceedings. International Conference on Gearing. Page 170. (Institution of Mechanical Engineers, London.)
8. DAVIS, W. O. 1953. N.A.G. Press Ltd., London. " Gears for Small Mechanisms."
9. SAYCE, L. A. " The Production of Diffraction Gratings." Endeavour 12, No. 48, 1953.
10. BURCH, J. M. " Photographic Production of Gratings for Measurement." Research, volume 13, No. 1, 1960.
11. GUILD, J. 1956. Oxford University Press, London. " The Inference System of Crossed Diffraction Gratings."
12. WILLIAMSON, D. T. N. 1954. Machinery Lloyd (European edition), 26, No. 16A, 51. " Automatic Control of Machine Tools."
13. TIMMS, C., SAYCE, L. A., and AITCHISON, T. W. Patent Application No. 17604/58. " The Application of Circular and/or Linear Gratings to the Measurement of Errors in the Motion of Mechanisms including Machine Tool Elements."
14. ——————. " Inductosyn — Principles and Applications." Inductosyn Ltd., Woking, Surrey.
15. NAVARA, B. " Czechoslovakian System for Improving the Accuracy of Gear Hobbing Machines." *Machinery,* volume 95, page 575, September, 1959.
16. PAGE, H. H. 1958. Proceedings. International Conference on Gearing. Page 302. (Institution of Mechanical Engineers, London.)
17. NEWMAN, A. D. 1958. Proceedings. International Conference on Gearing. Page 313. (Institution of Mechanical Engineers, London.)
18. PLUMB, R. C. 1958. Proceedings. International Conference on Gearing. Page 349. (Institution of Mechanical Engineers, London.)
19. SYKES, A. 1959. *The Engineer,* 13th November. " Allowable Load on Helical Gears."
20. FLETCHER, H. A. G. 1958. N.E.L., East Kilbride (Mech./Met. Reports 127 and 139). " Factors Influencing the Overall Efficiency of a Spur Gear Drive."
21. GREGORY, W. T. 1958. Proceedings. International Conference on Gearing. Page 264. (Institution of Mechanical Engineers, London.)
22. BERRY, G. 1959. N.E.L. East Kilbride (Mech./Met. Report 135). " Use of Magnetic Tape Recordings in the Measurement and Analysis of Gear Noise."

PRECISION GRINDING RESEARCH
(PART 2)

by H. GRISBROOK, B.Sc.(Birm.), A.M.C.T., M.I.Prod.E.

Department of Engineering Production,

University of Birmingham.

DISCUSSION AND CONCLUSION

general

These preliminary investigations, aimed primarily at exploring the possibilities of the equipment, have covered so many factors that quantitative results, from which complete conclusions could be drawn, could not be expected and only trends can be indicated.

Some results comparable with those of earlier investigators having been achieved, justify acceptance of rather more controversial results as a basis for further investigations and development by means of this equipment.

The findings indicate that the mechanism of grinding can consist of two forms; the first, under conditions of high metal removal, is one predominantly of cutting and in the second, as the rate of metal removal approaches some critically low value, rubbing predominates.

the dynamometer

The degree of consistency in the results so far analysed is sufficient to prove the dynamometer to be reliable under the conditions imposed by a table traverse speed of 36 f.p.m., a depth of cut 0.0003 in. on $\frac{1}{2}$ in. work width, and wet grinding conditions.

The maximum vertical and horizontal loadings registered were 71 and 21 lb. respectively. These occurred under very severe conditions and loads of 25 and 10 lb. can be said to be the normal maxima.

table traverse speed

The effect of grinding load on the speed of table traverse was small. Differences in speed between the two directions of traverse complicated the problem and until satisfactory balance in the hydraulic mechanism is obtained, it cannot be concluded that a significant difference results due to the direction of the grinding load.

That such an effect may exist was suggested by the results, in which the crude mean of the ratio of speeds, under load and free, is just below unity in up-grinding and just above in down-grinding.

If any surprise should be occasioned by this difference it should be that it is so small. The grinding force is opposed to the hydraulic traverse force in up-grinding, while in down-grinding it is contributory to it. Thus it must be concluded from the results obtained that the design of the hydraulic mechanism and the power of the oil motor are sufficient to reduce this effect to a negligible amount.

However, it must be realised that the actual forces recorded are directly those of grinding and are

---

This Paper — condensed from a research thesis — the first Part of which appeared in May, is a first report on a current research project in the postgraduate Department of Engineering Production in the University of Birmingham.*

The work is being carried out on a Churchill 8 in. × 16 in. Plain Surface Grinding Machine, equipped with a specially designed dynamometer capable of operating at a maximum table traverse speed of 38 ft. per minute under wet grinding conditions.

To indicate the need for this investigation and the significance of the preliminary findings, this Paper began with a survey of previous work.

* H. Grisbrook: "Precision Grinding" Official Degree Thesis. Department of Engineering Production, University of Birmingham, May, 1959.

independent of the forces in the hydraulic system. The grinding force is transmitted through the vertical cantilever post to the table and it is from the deflection of this cantilever that the force is measured, and not from any differences in the pressures in the hydraulic circuit.

spindle speed

The loss of wheel speed in grinding, where the wheel spindle is driven directly from a squirrel cage motor, is to be expected and under workshop conditions, with this machine, will not exceed 8% of the rated speed.

It is related to the torque-slip characteristics of the motor as shown in Fig. 6.

However, under research conditions it becomes an embarrassment, because it is desired to determine the reaction of a wheel at a specific wheel speed. Wheel speed is an important criterion of the load per grit and hence to the reaction of the bond. As the speed falls the intensity of load on the wheel face increases, hence the load per unit grit increases. On the other hand, chip thickness *varies inversely* as the square root of the wheel speed and *specific energy decreases* with *increase in chip thickness*. Thus a complex situation arises when the wheel speed is not maintained constant.

To balance the effect of this loss of wheel speed, the value of chip thickness, and of specific energy, have been calculated from actual minimum wheel speed.

Thus it is reasonable to conclude that, as loss of wheel speed will be inevitable under workshop grinding conditions, the findings of this research, where the loads are comparable, will be analogous with normal precision grinding conditions. However, future work must include a mathematical analysis, based on further experiment, to determine the significance of loss of wheel speed.

It can be reasoned, on a qualitative basis, from the experience gained during these experiments, that loss of wheel speed can be fortuitous, as it will reduce the effective hardness of the wheel which could otherwise be too hard for the conditions.

Nevertheless, the current research may be in question where excessive loss of wheel speed is a combined effort due to belt slip and torque-slip resulting from loads higher than those anticipated for this machine and, therefore, a more powerful drive is desirable in future investigations.

depth of cut

Runs with downfeed in excess of 0.3×10^{-3} had to be stopped due to excessive load.

This depth of cut would appear small when compared with normal practice, but it must be considered in relation to the width — ½ in. — of cut.

Normal practice adopts relatively small, 0.50 in., cross-traverse and to obtain the area of cut equivalent to the maximum in this current research, namely 0.00015 sq. in., the downfeed would need to be 0.003 in.

Such a downfeed is a reasonable maximum for this machine.

The response of the wheelhead slide, to these fine increments of feed, was checked during the development of the automatic fine feed. It was found that, under the extreme condition of 0.0005 in. increment, the total of any group of four consecutive increments was constant.

Once the deflections of the machine and dynamometer have been accommodated these small downfeeds prove to be consistent increases in cut at each stroke.

chip thickness

As discussed under the heading of wheel speed, chip thickness has been calculated using actual minimum wheel speeds. It will be seen, by reference to Fig. 7, that chip thickness will vary along the length of the work, commencing at a small value at nominal wheel speed and increasing to a constant thickness when the stable minimum speed is reached. Hence it proved desirable to use the values which occur at minimum wheel speed.

forces

The pattern of forces during a run has been explained, and illustrated in Fig. 8, where the four regions are indicated.

The rise to a peak in Region I has been attributed to the effect of wheel truing and thus some explanation is called for to justify the method of wheel truing adopted.

Following the experience of M.I.T. [1] with inconsistency resulting from wheel truing, and bearing in mind that Tarasov depreciated the practice of truing to spark out because it resulted in a dull wheel, it was still considered of vital importance that a true wheel was the first essential. Landberg [7] had shown that wheelwear amounted to the development of lobes on the periphery of the wheel, so this must be corrected by wheel truing.

At M.I.T. [1] a number of runs were made with only one wheel truing; this it was felt would superimpose the effect of wheel wear on succeeding runs.

Hahn [9] had shown, in his Fig. 4, that when comparing the effect of different rates of traverse during truing, the different conditions of wheel would eventually approximate to the same condition of grinding. Pahlitzsch and Appun [23] also confirmed this.

Thus, a method of truing was adopted which would guarantee a true wheel free from lobes, truing would precede every run, the effect of the dull wheel could be expected to wear off, and the wheel condition resulting from natural breakdown would be consistent. Truing would also remove the blackened loaded effect of the previous run.

Thus Region II, Fig. 8, resulted from a natural condition of wheel where the effect of truing to spark out has worn off and the nearest approach to a truly round wheel is obtained.

Helfrich [20] warns against the dangers of lack of homogeneity in the structure of a grinding wheel which produces an out-of-roundness in crusher dressed wheels. This is confirmed by the lobes on Landberg's [7] worn wheels, so it was concluded that

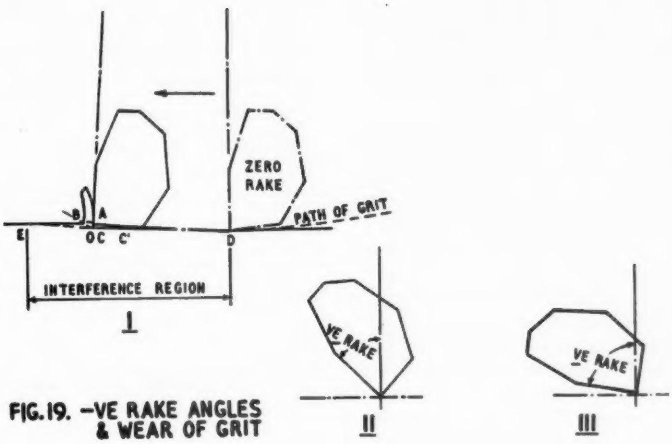


FIG. 19. –VE RAKE ANGLES & WEAR OF GRIT

crusher dressing would be less consistent than the diamond. Helfrich considered this possibility.

It still remains for future investigations to explore the results of different dressing techniques and these must include wheel crushing in spite of Helfrich's elevation of the process to the arts.

The general pattern of the behaviour of the forces as grinding proceeds conforms to the curves established by Landberg [7]. The majority of the runs in the current experiments were not continued long enough to produce a wheel sufficiently dull to develop excessive vibrations. This condition did, however, develop during occasional runs and a decrease in forces followed. By combining the separate results a complete pattern of change in forces during grinding, as suggested by Landberg, was repeated.

For the slower traverse speeds Region II, Fig. 8, was of short duration. This is attributed to the reduced chip thickness, rubbing predominates, and the rate of dulling of the grit increases rapidly, accompanied by an increase in forces.

Hahn's "Rubbing Grain Hypothesis" is of particular significance in these conditions of small chip thickness.

rake angle

In Fig. 19, the possible effects of grit shape and its orientation in the wheel are shown. The chosen shape of the grit is optimistic, having a tool angle something less than 90°; there will be many grits offering less effective cutting profiles to the work than this. Such a grit can be presented at any angle to the work according to chance. Three possibilities are indicated. At position (i), Hahn's notation of his Fig. 5 is introduced. Hahn expounds that the rubbing area OC will, due to wear, extend to OC_1. He continues by referring to the chip grit interface OA and the shear plane OB and concludes that these three areas OA, OB and OC may be thought of as heat sources. They can likewise be considered as pressure sources and contributary to the tangential force F_T.

This grit in Fig. 19 can occupy positions progressively anti-clockwise, as at (ii) and (iii), offering an increasing negative rake angle.

With all these possible alternative positions with a grit having this particular tool angle, the mean negative rake will be 45°. It can be assumed that the included angle of the cutting portion of a grit can vary between 70° and 130° with a mean angle of 100°. Thus the average rake angle will be between –10° and –90°, i.e., –50°.

With such large negative rake angles the possibility of producing conventional chips, along plane OA, decreases as OC increases due to wear and also as the theoretical chip thickness decreases below a critical value.

Thus as a critically small value of t is reached, and wear on face OC develops, the force F_T will become solely the result of the friction force on OC and there will be no contribution from the area OA and consequently OB, as these will not exist.

Thus, as wear develops in conditions of critically small values of t, the mechanism will pass from a condition of predominantly cutting to one of rubbing.

This is supported by the curves in Fig. 9, where for 8 f.p.m. Region II is represented by a point of inflection for F_T and there is a continuous and rapid rise of F_N until the region of vibration is approached. For 15 f.p.m. there is a slight improvement relative to the slower speed.

The grit size governs the spacing "C" of the grits in the working face of the wheel as determined by Guest [3]. With finer grits the forces increased.

Under similar grinding conditions the number of chips per unit volume of metal removed will be higher for the smaller grit at a rate of the square of the nominal grit size. Dynamic shear stress increases with the decrease in size of chip, hence forces are higher for smaller chips, i.e., for finer grits (Reichenbach, 9).

The region of stable grinding conditions was shorter for the smaller grit. This can be related to

the rubbing grain hypothesis. With the same amount of attrition on each grit there will be a higher rate of increase of area with the higher concentration of grits, and therefore an increase in the rate of glazing (wheel wear).

The increase of forces with the harder grade of wheel was to be expected. The grit will be more firmly supported by the bond, therefore wear by attrition will be more prevalent in the harder wheels.

In the softer wheels, bond post rupture will limit the magnitude of the forces which the wheel can resist.

Reduction of forces with the softer wheel is emphasised in Fig. 15, where forces increase with harder wheels, and this increase is greater at the lower work speed, but with the softer G wheel there is little difference in forces between the 15 and 36 f.p.m. work speed.

Some degree of dulling of the grit before dislodgement must be accepted in a grinding operation and the ratio of wheel wear to metal removal will be related to this. The amount of dulling permissible will be dependent upon the application and will be related to the permissible loads.

Therefore, merely to state that forces are lower with softer wheels, while obvious, serves no useful purpose.

In future, information must be obtained which combines the effect of wheelwear, forces, table speed and depth of cut and wheel hardness.

It is in this connection that it is to be regretted that during these experiments, loss of wheel diameter (rate of wheel wear) was not measured and the grind-ratio thus established.

The difference between forces in up-grinding and down-grinding varies with table speed, the ratio F_{T_U}/F_{T_D} being unity at approximately 10 f.p.m., for the coarser grit wheels, and thereafter increases with increase in table speed, Fig. 10. This difference is mainly confined to the tangential forces; the normal forces, N, are substantially the same in both directions of grinding.

However, where very slight differences in F_N did occur, the tendency was for the down-grinding forces to be higher, at lower table speeds.

It can be implied, by reference to Fig. 11, that this difference could be related to the increased friction as OC increased due to wear, coupled with the critically fine chip thickness obtaining at these low table speeds. Thus, it could be concluded that the rubbing end grain is of more significance in up-grinding than in down-grinding.

There is here an analogy with upcut and downcut milling where it is accepted that more rubbing occurs in upcutting as the cutter tooth engages the metal and prior to the actual formation of a chip. In milling also, great importance is attached to the need for maintaining sharp cutters and in practice 20% increased cutter life between grinding (sharpening) is obtained when downcutting is compared with up-cutting.

Thus again there is evidence for support of the "rubbing grain hypothesis" [9]. The difference may result from the difference in chip thickness; this can be demonstrated by a geometrical analysis of the two conditions of up- and down-grinding.

The individual wedges of metal removed per grain have closely the same volume in each case, but those for upcut are longer than for downcut, hence the average and maximum thickness of chip per grain is greater in the case of downcut [17].

However, there is another factor to be considered: dynamic shear stress is a function of the thickness of the chip.

Therefore, for longer and thinner chips — as is the case in up-grinding — higher stresses will result in higher forces. As traverse speeds increase the difference in chip-thickness for the two direction of traverse increases and the ratio of F_{T_U}/F_{T_D} also increases.

The full significance of these rival factors calls for very considerably more investigation and the correct balance of traverse speeds will then be very important.

coefficient of grinding

It is because the coefficient in grinding is so much lower than that of single point cutting that it must be accepted the grinding operation involves factors that are either absent from the single point operation or, if present, assume considerably more significance because of their relative size:

(i) There is the question of rubbing which can be negligible in single point cutting.
(ii) The much larger values of negative rake angles presented by the grit to the work.
(iii) Chip thickness also plays an important role [15].

These three factors are interrelated and predominate at slow table speeds (smaller chip thickness) where the coefficient of grinding is at its lowest, as seen in Fig. 13.

Rubbing, as wear develops, reduces the value of the coefficient of grinding (Fig. 11). Thus the coefficient of grinding falls as grinding becomes less efficient as a means of removing metal. The less it operates as a cutting operation, the more remote it is from the mechanism of milling, the lower is the coefficient of grinding.

Even under conditions of relatively high rates of metal removal, where conventional type milling chips are produced, the presence of some abrasion, of large negative rake and of minute chip thicknesses, the similarity with milling is mainly one of appearance. It is vastly different in speeds and size of chip.

In almost everything except geometry, the grinding operation is very different from milling and a coefficient of grinding of 0.5 contributes to this conclusion.

specific energy

It has been shown that specific energy is related to the chip thickness, it decreases as chip thickness increases, but the relationship is different depending upon the variables of work speed and depth of cut.

The results of this research also indicate that the hardness of the wheel, and its relationship with the conditions, is also a factor limiting the specific energy which must inevitably be lower with softer wheels.

At 36 f.p.m. work speed, specific energy was independent of hardness of material when using the M wheel, but with the soft wheel, energy was *lower* for the *harder* material.

This relationship between grade of wheel and hardness of material is important in grinding research.

The problem posed by two values of specific energy for the same thickness of chip can be solved by combining the two variables of depth of cut and workspeed into one of rate of metal removal :

$d \times V_M \times w$. in cubic in. of metal removed per min.

By plotting specific energy against rate of metal removal the two graphs A and B, Fig. 18, were obtained.

From the current research sufficient material is available for only two examples, but these two are sufficient to indicate how valuable this relationship promises to be.

Before analysing the two graphs, it is important to emphasise that the values plotted have been calculated from loads and actual (not nominal) speeds, obtained under the stable conditions previously explained.

It is also worthy of observation that in only two of the runs used, one in each graph, did the loss of wheelspeed exceed 8%, being 10.5% for one run in A and 12.5% for one run in B.

Both graphs emphasise the validity of the "rubbing grain hypothesis" and reinforce the suggestion that as the rate of metal removal falls a critical condition (of critical chip thickness and degree of dullness of grit) will arise where the mechanism of grinding changes from one predominantly of cutting to one of abrasion.

For the conditions of metal removal above this critical condition there is almost constant specific energy independent of rate of metal removal.

The actual relationship obtained from the graphs are :-

$$U_s = 16 - 66R_M \quad \text{for A}$$

and

$$U_s = 15 - 80R_M \quad \text{for B}$$

R_M = rate of metal removal cubic in. per min.

There are two distinctions between the two graphs :-

A is for a J wheel on 800 V.P.H. Steel and,
B is for a G wheel on 200 V.P.H. Steel.

This complicates comparisons.

However, it is shown (Fig. 15) as far as specific energy is concerned, that a soft G wheel is indifferent to work speed but susceptible to hardness of work material, and the harder M wheel is indefferent to hardness of work material at the higher speed. The effect of material hardness for a J wheel is not greatly different from the G wheel, but the effect of speed is more pronounced.

Thus the effect of hardness of work material on comparison between A and B will be small and will concern only the left hand portion of the graphs.

For rates of metal removal below the critical value, specific energy rises rapidly; it maintains a straight line relationship but at a very different slope. Here, to quote Hahn [9] "... there is no chip, metal is removed as dust ..."

This is Region V of Fig. 9, which is referred to in the Authors' (Reichenbach *et al,*) closure of 15, where they go on to state "... this would lead to an infinite value of specific energy".

The possibility of the specific energy approaching infinity, however, will be seen from the graph to be determined by the hardness of the wheel. For the softer wheel the angle of the slope is less and a maximum finite value for specific energy is approached.

Two reasons are suggested for this :-

(i) the wheel is sufficiently soft to permit of bond post rupture before appreciable dulling of the grit develops and thus new and sharp grits are constantly brought into action; and

(ii) the maximum energy a wheel can transmit is determined by the strength of its bond.

Suggestion (i) would explain the slope of this portion of the graph. Thus the slope will increase with the hardness of wheel and possibilities of metal removal, even as dust will decrease with increasing hardness of wheel, and specific energy will approach infinity.

Future experiments using wheels of grades G, H, I and J, on one hardness of material, resulting in progressively increasing slope, would confirm this suggestion.

Another feature of these two graphs is the point at which the mechanism of grinding changes. This occurs earlier for the softer wheel. In this connection Fig. 16 may suggest the answer; here the normal force F_N is plotted and proves to be less for the G wheel when operating on the softer steel at the lower speed. At low work speeds, the resultant of F_N and F_T will act along a line nearer to the normal to the wheel surface than will obtain at higher workspeeds. This will approach the conditions of wheel crushing and to this a soft wheel will respond sooner than a hard wheel.

Measurement of wheel wear in future work will throw light on the possibility and on suggestion (i).

Grit size was found to be related to the forces and also to the rate of increased dulling. A few runs with the 36 grit wheel are therefore introduced at A, Fig. 18, and there is a vague suggestion that grit size can affect the position of the critical rate of metal removal.

Again, future work must also include this variable.

Horsepower required for grinding is determined by the right-hand portion of the graphs; there is little

power needed in finishing to which the left hand end refers.

A tentative relationship between U_s and R_M has been established and confirmation of this by further investigation will enable the required horsepower for prescribed conditions of metal removal to be determined. In addition to the power required for grinding there will be that required to drive the spindle under zero load, which is exceptionally high (in the region of 0.5 H.P. for this machine) and also an amount to meet the increase in forces as the wheel dulls (glazes) or loads.

This last addition will involve the hardness of the wheel and its suitability to the conditions. This is one of the problems anticipated by Hahn when he stated that "... any grinding theory if it is to be realistic, whether it is based on grinding energy or otherwise, should contemplate the very real difference between sharp or dull grits and between soft and hard wheels".

Fig. 18 would appear to go a long way towards satisfying Hahn's specification and an extension of these experiments, with the inclusions suggested in this discussion, will be necessary before any firm conclusions can be reached.

acknowledgments

This research has been encouraged by the active co-operation of Sir Greville Maginness, of The Churchill Machine Tool Company Limited, and by the help and advice so freely given by Mr. M. D. Molloy, of the Universal Grinding Wheel Company Limited.

The conscientious assistance of Messrs. G. L. Lane and S. Zur, post-graduate students, has been an invaluable contribution during the sequence of the experiments.

The service of Mr. D. N. Jones of E.M.I. Electronics Limited is also gratefully acknowledged.

The guidance of Professor N. A. Dudley in all phases of this work is very sincerely acknowledged.

REFERENCES

1. MARSHALL, E. R. and SHAW, M. C. "Forces in Dry Surface Grinding." Trans. ASME., Vol. 74, 1952. page 51.
2. GUEST, J. J. "Grinding Machinery" Published by Edward Arnold, 1915.
3. GUEST, J. J. "The Theory on Grinding — Proceedings." I.Mech.E., October, 1915. page 543.
4. BACKER, W. R., MARSHALL, E. R. and SHAW, M. C. "The Size Effect in Metal Cutting." Trans. ASME., Vol. 74, 1952, page 61.
5. BACKER, W. R. and MERCHANT, M. E. "On the Basic Mechanics of the Grinding Process." ASME Paper No. 56 - A - 43.
6. OUTWATER, J. O. and SHAW, M. C. "Surface Temperature in Grinding." Trans. ASME., Vol. 74, 1952, page 73.
7. LANDBERG, P. "Experiments on Grinding." College International pour l'etude scientifique de techniques de production mechanique. April, 1956.
8. McKEE, R. E., MOORE, R. S. and BOSTON, O. W. "Results of an Investigation of the Removal of Metal by the Process of Grinding." Trans. ASME., Vol. 69, 1947, page 125.
9. HAHN, R. S. "Relations Between Grinding Conditions and Thermal Damage in the Workpiece." Trans. ASME., Vol. 78, 1956, page 807.
10. HAHN, R. S. "The Effect of Wheel-Work Conformity in Precision Grinding." Trans. ASME., Vol. 77, 1955, page 1,325.
11. WILLS, H. J. and INGRAM, H. J. "Fine Grinding and Lapping." Machinery's Yellow Back Series, No. 19.
12. FRISCH, J. and THOMSEN, E. G. "Residual Grinding Stresses in Mild Steel." Trans. ASME., Vol. 73, 1951, page 337.
13. LETNER, H. R. "Residual Grinding Stresses in Hardened Steel." Trans. ASME., Vol. 77, 1955, page 1,089.
14. TARASOV, L. P. and GROVER, H. G. "Effects of Grinding and other Finished Processes on the Fatigue Strength of Hardened Steel." Proceedings, ASTM., Vol. 50, January, 1950, page 668.
15. REICHENBACH, G. S., MAYER, J. E., KALPAKCIOGLIN, S. and SHAW, M. C. "The Role of Chip Thickness in Grinding." Trans. ASME., Vol. 78, 1956, page 847.
16. LANE, G. "Energy — In Wet Surface Grinding." Unpublished Thesis, University of Birmingham, 1958.
17. HUTCHINSON, R. V. "Do We Understand the Grinding Process?" Journal S.A.E., 1938, page 89.
18. SHAW, M. C. "The Grinding of Metals." Conference of Technology and Engineering Manufacture, I.Mech.E., 1958.
19. PAHLITZSCH, G. "Distribution of Temperature in a Cylindrical Grinding Machine, from Starting to Steady State." Microtechnic, No. 5, Vol. 10, 1956, page 215.
20. HELFRICH, E. C. "Theory and Practice of the Crush-Dressing Operation on Grinding Wheels." Trans. ASME., November, 1948.
21. MAYER, J. E. and SHAW, M. C. "Grinding Temperatures." Paper presented to the ASLE., 11th Annual Meeting, Pittsburgh, 5th April, 1956.
22. GRISBROOK, H. "Reaction of Grinding Wheel Bond." Mechanical World, Vol. 110, 7th November, 1941, pages 326 - 327.
23. PAHLITZSCH, G. and APPUN, J. "Effect of Truing Conditions on Circular Grinding." Industrial Diamond Review, Vol. 14, 1954, pages 185 - 189 (September, pages 212 - 217 (October).

FACTORY DESIGN FOR THE FUTURE

by W. ALLEN,
B.Arch., A.R.I.B.A.

Superintending Architect,
Building Research Station.

Mr. Allen was born in Canada in 1914 and received his education in architecture there.

He came to the United Kingdom in 1936 and practised privately before entering the Building Research Station shortly before the War.

He is now the Superintending Architect of the Station and has been a member of the Council of The Royal Institute of British Architects for seven years. Factory design has been one of his principal interests.

This Paper was presented to the Midlands Region of The Institution of Production Engineers on 7th April, 1960.

EXPENDITURE on new factories in this country is running at a rate of between £250,000,000 and £300,000,000 per annum. After housing, which absorbs about £600,000,000 annually, it is the largest category of building expenditure. At the same time we have in use a great deal of old factory space. In London and the Midlands for example about a sixth of the factories apparently are more than 60 years old*. Much of the old space and some of the new does not permit the development of modern production technology and is a drag upon the country's efficiency. Professor R. W. Revans† gave it as his opinion not long ago that over 90% of the industrial buildings within one mile of his University of Manchester "should be totally demolished without expectation of any salvage whatever." By what criteria should the value of factory space be assessed?

These have evidently been rather vague in the past. Emphasis shifted from multi- to single-storey working during the period between the Wars because of advantages for production, especially the use of flow-line methods and modern handling techniques, and because it was cheaper to develop this way if cheap land could be obtained. Modern transport made a contribution to putting much of this within reach. Consideration of the criteria did not generally go very far beyond this simple decision, and the factories themselves have in many cases proved disappointing buildings, old-fashioned and restrictive

* From an unpublished survey by the Building Research Station.

† Conference on Cost Control at the York Institute for Advanced Architectural Studies, July 1959; available from The Royal Institute of British Architects.

before their time, and sub-standard in many respects from the outset. Many were little more than bare shelter, keeping out the wind and the wet, letting out the heat, and trimmed to the minimum in spans, heights and framing. There were a few honourable exceptions; the Boots factory at Beeston, near Nottingham, and Van Nelle in Rotterdam are examples, though both are mainly multi-storey factories.

A great deal of production space was built during the War, much of which was technically better in some respects but decidedly utilitarian, and it was sometime after the War before much new space was put in hand. When development became active again much of it resumed where war-time design had left off, but with one or two further technical improvements, especially in respect of thermal insulation (heating standards had gone up, while a fuel shortage prevailed) and lighting. At the same time a new note was sounded, partly a response to the developing concept of the welfare state, and partly to the lead given by some of the pre-War factories. For it was argued that the operative in a factory was as much entitled to good surroundings as say a child at school, or a worker in an office, and quite a number of factories were built whose chief feature was an architecturally pleasant environment. It was held to be a proper objective in itself, and probably indirectly beneficial for output; but production technology as such did not play much part in defining the trend of development except in isolated factories, generally of a type where the plant was on a scale which dominated the factory.

In America matters had taken a rather different course from an early date. In 1922 Albert Kahn, an architect friend of Henry Ford, was infected by the new thinking about mass production and set himself up with some engineering associates to specialise in factory design. Two or three other groups of designers soon entered the field and vigorous thought was given to design for modern production, both by the designers and their clients. Progress was characteristically rapid, and by 1929 one of the design firms put in hand a building of such advanced character that as factory space it is difficult to criticise in any respect today. Moreover, no trend in production technology of which I am aware at the moment seems likely to make demands which the building would be unable to meet, and it is quite possible that in another 30 years this building will still be good production space. It has reasonable height and spans, a simple but robust frame, a flat trussed roof, no daylight, a sound-absorbent and heat-insulating ceiling, full air-conditioning, fluorescent lighting, and a simple, clean plan with the offices, locker spaces, toilets, etc., all under the same roof.

Initially no doubt it cost somewhat more per sq. ft. than the general run of factories at the time, but the firm — an old-established engineering company — claimed to be well-rewarded from the outset in production economies, and in terms of say 60 years'

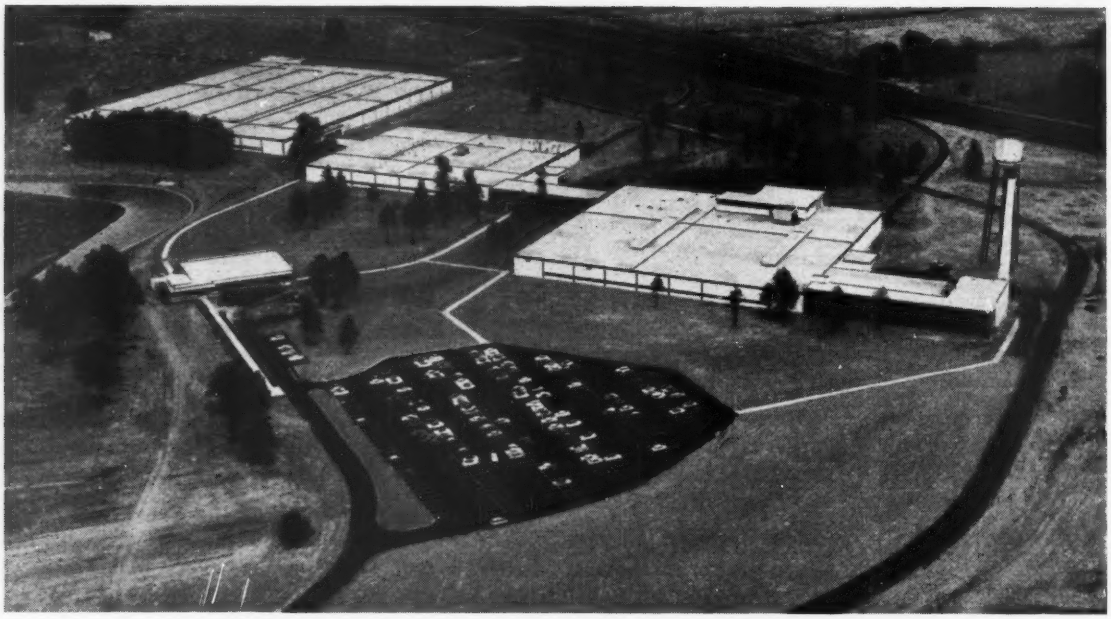


Fig. 1. The typical American factory; simple shapes, flat roof with ventilation plant projecting, and windows for a view only. In this case three related processes are separated for individual expansion.

Courtesy Johnson & Johnson — photographer: F. H. Higgins

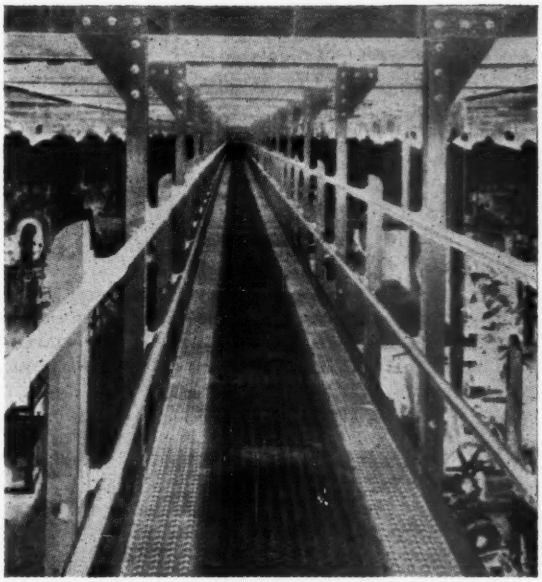


Fig. 2. Suspended overhead walkway for movement of personnel above working level.
Courtesy Simonds Saw & Steel Co.

use of efficient space they are bound to have made a very advantageous investment.

The depression of the 1930's stopped factory building in America, but some of the designers were invited to do work in Russia, and their concept of factories built to give flexibility for new production techniques was developed further there. Construction revived in the U.S.A. in the late 1930's, and of course flourished during the War period when the new type of factory was found very satisfactory. No fundamental changes have taken place in the concept since the War, and medium and large American factories now display a consistency of character which is in marked contrast to the variety in the British scene.

The emphasis on adaptability should be noted; there are few attempts to "tailor-make" factories to particular products or production layouts. There are of course the familiar exceptions of heavy plant which dictate something special; but for the most part the buildings are designed around a concept of possible rather than actual production requirements, and behind this lies the idea that the resulting adaptability will ensure that the building gives its owners a long life of efficient conditions and a high potential re-sale value, and that the country will get a high return in productivity on the capital invested as well as a high degree of resilience to meet changing circumstances.

It is the high return on the investment which gives the typical American designer and client their common starting point for a project. The factory is expected neither to be mere shelter nor to reach out merely for a pleasant environment, but to facilitate production. This is the return they expect on their investment and they set out to maximise it. They do not mind spending adequately where a dividend of this kind is likely, but there is a notable absence of signs of ill-judged expenditure. The chief criticism an architect might make would be a "short-fall" on pleasantness in the environment, which need not be neglected in securing efficiency in other ways.

The Building Research Station has had for many years interests in various different aspects of factory design arising out of its programmes of research. Five years ago, impressed by the American outlook, it began to organise a study of factory design as a whole, and was fortunate enough to encounter a related interest on the part of the Midland Regional Board for Industry, whose special concern was to evaluate multi-storey construction. The Board was anxious for the work to be done as quickly as possible and offered to support it in various ways. The results of the investigations are currently being published as a series of monographs by H.M. Stationery Office‡. Much of the remainder of this Paper draws upon this work.

factors affecting production and operation

It is unlikely to be disputed that thinking about the design of production space should begin with operating and production requirements, which can conveniently be divided as follows for discussion:

- Arrangements for incoming and outgoing goods.
- The internal movement of goods and plant.
- The provision of processing aids and the removal of wastes.
- Production requirements for structural spans, heights and load-bearing.
- Air control.
- The efficiency and well-being of operatives.
- Protection against loss of production due to fire.

There are a number of other important matters under which management has to consider its brief for design, but those mentioned are direct interests of production and handling engineers and include the decisive parameters of sound design for production space. None of them is in itself unfamiliar either to these categories of engineers or to experienced factory designers, but there is still novelty in considering them as an interlinked pattern, and it is the failure to see them in this way that has led to many disappointments in design. Professional engineering skill tends naturally towards specialisation in order to secure a mastery in detail over some particular aspect. The design of a factory, as of any other building, has to merge all aspects into an organised arrangement in which conflicts have been resolved and all parts complement one another. In order to do this the main requirements of each aspect must be grasped at policy level. It is one of two urgent needs in factory design today that those

‡ Factory Building Studies, published by H.M. Stationery Office. The following have been issued: Modern Multi-Storey Factories; The Lighting of Factories; Floor Finishes for Factories; Structural Loading.

responsible for briefing on the client's side should try to see the pattern whole in this manner.

The other need, equally important, is to make decisions not on the basis of immediate intentions for production, but in terms of what the future might reasonably call for. This is not so difficult as might be imagined if the matter is approached systematically, and some scales and limits are identified within which the decisions have to be made. In what follows no attempt is made to consider any production matters in detail; instead, it will be so far as possible an illustration of the type of approach which has just been described.

incoming and outgoing circulation

No comparative study of different ways of handling incoming and outgoing traffic is known to the author although every factory built has had to solve the problem one way or another. The different solutions could no doubt be reduced to a comparatively small number of systems and a certain number of standard problems can be foreseen.

The relation between access points and factory should be carefully considered. Too many roads can cut up a site badly and waste valuable land, as well as run up costs. If access points are to have manned controls, there is an additional argument for cutting down their number, partly because of the cost of the buildings but chiefly because of the cost of manpower. If the capitalised value of a man is taken at 18 - 20 years' pay, it can be worth spending considerable sums if thereby changes can be made in a layout which will reduce manpower needs.

Leaving aside the question of employees' parking as being only indirectly related to what is being discussed, consider next the reception and despatch arrangements. One has to decide whether to separate or associate them. Here again it seems safe to argue that, as a general rule, combination is likely to be the less expensive because it will minimise on roads, manpower, and handling gear. No doubt there will be occasions, especially in large establishments, where it will be preferable or necessary to put receipt and despatch in different places.

The onload/offload arrangements present the next problem and are important because they affect the vital question of the floor-level. It has often been the practice to have a loading-dock raised approximately to the level of lorries and railway wagon floors, for this probably seemed cheaper than lowering lorry standing areas or railway tracks, and is undoubtedly cheaper than raising the whole floor. However, the question needs consideration on a broader basis. If fork-truck handling is likely to be used in the factory then it is often valuable to have the floor at ground level so that the trucks can go in and out freely. At the same time it may be desirable to be able to take trucks directly to the mouth of a lorry or even inside it, to minimise man-handling. The raised loading bay then generally becomes impracticable, because the trucks can climb only very shallow ramps. By this argument one arrives at the conclusion that it is likely to be wise to envisage lowering the lorry standing area and even railway tracks, in order to leave a flat floor at ground level. All other arrangements seem likely to be more restrictive though a number of particular solutions can be found, especially on sloping sites.

internal circulation

Internal circulation requires separate consideration of goods and plant. Movement of personnel will be omitted from this discussion as not being immediately related to production.

Goods — In single-storey factories the question which chiefly affects the design of the building is the extent to which overhead circulation is likely to be required, and this can be divided into two parts, the use of conveyors and the use of cranes.

Let it be assumed for the moment that cranes are not to be generally employed. The nature of the problem to be considered then is a simple but important one — whether or not to make the clear height of the factory sufficient to allow conveyors and their loads to pass freely over plant and to cross other conveyors and obstacles. Note particularly that the question is not posed in terms of an immediate intention, but as a provision for potential use. This is not the only question affecting height, and others will be discussed; but it is one to which an answer must be given. A 12 ft. or 14 ft. clear height virtually precludes overhead gear except of the lightest type, but 18 ft. permits it, and a choice between dimensions of this order has often to be made today.

If the choice is made in favour of providing the necessary height, then it follows that some specification of the likely loads and possible types of conveyor must be made so that the overhead structure can be designed suitably.

Decisions about cranes appear to present rather more difficulties in practice than might have been expected. They represent a considerable item of expenditure which varies a good deal depending on span and load-carrying capacity, and the span in turn influences the main structural design and this has a further repercussion on costs. One of the difficulties sometimes is to decide on the lifting capacity, especially if there are occasional loads much in excess of the average.

Another matter that has often to be considered is the possibility of transfers. It is one of the precepts of handling that when a load is lifted it should not be deposited or change hands until it is where the next work is to be done upon it. With certain types of crane it is not easy to make transfer arrangements and one is limited to movement back and forth along the bay. Other possibilities appear to have attracted more attention in America than here, and there are installations offering considerable freedom for transfers. A recent type of crane which facilitates this is hung from the overhead structure instead of being supported at the stanchions. The roof framing must naturally be robust, but there is the compensation that the crane girder itself can be carried at several points and therefore can be relatively light.

Moreover it can be as long as the maximum span, for in a factory with large spans in one direction it can readily be arranged to traverse the structure. Conventional cranes would usually keep to the shorter span.

In a matter of this kind the full range of possibilities must be known, together with the limiting factors, before those who have to take decisions about production and handling facilities are well-placed to do so. It appears to be one of several points at which conveniently organised information is not available at the present time.

The problems of multi-storey factory design have been more extensively discussed in one of the Station's Factory Design Studies than is possible here, but certain points must be drawn into this discussion.

The outstanding matter requiring a clear-cut decision is whether provision is to be made for using fork-lift trucks for handling goods on upper floors. The answer to this affects the design and cost of the building considerably, because without trucks, floors would normally be designed for loadings only up to a maximum of about 250 lb. per sq. ft., while if trucks are to be permitted then loadings in excess of the equivalent of 750 lb. per sq. ft. would have to be the basis of design. If more than one truck is likely to be employed per floor, then the probability of their meeting must be envisaged, with a corresponding increase in the load for which provision must be made. If storage is to take place on an upper floor then the weight of stores plus the loaded truck addressing the stack may become the critical factor, unless the whole is designed for the conjunction of two trucks.

While these floor-loading figures perhaps seem rather formidable, the fork-truck is a valuable handling tool and an inadequate floor may therefore put very damaging limits on the working efficiency of the building which it would be difficult and expensive to rectify during its life.

An incidental point of some importance is that if trucks are to be used on upper floors, lifts must be available which can carry them, preferably with their load; and the gates must be able to receive the masts. This is a reminder of the importance of looking at each handling problem systematically by following it through each stage of its use in order to foresee all the ways it affects the building.

The vertical movement of goods is, of course, the point where operating efficiency usually comes up against its greatest difficulties in multi-storey factories. Various kinds of plant are in existence for the purpose, but the impression one forms is that it is not often regarded as giving the same satisfaction as a horizontal layout. Perhaps the plant itself is less well thought-out than it ought to be; perhaps the lack of a visual link makes it less easy to run; certainly the cost and inconvenience of cutting holes in concrete floors seems likely to restrain some managements from making changes that ought to be made, though a few say this is not as serious a matter as it seems.

An unfortunate feature of vertical perforations is the risks they present for the spread of fire.

Plant — If plant layouts are to be kept tuned to a high level of efficiency, minor or major adjustments must often be made to them and facilities for moving

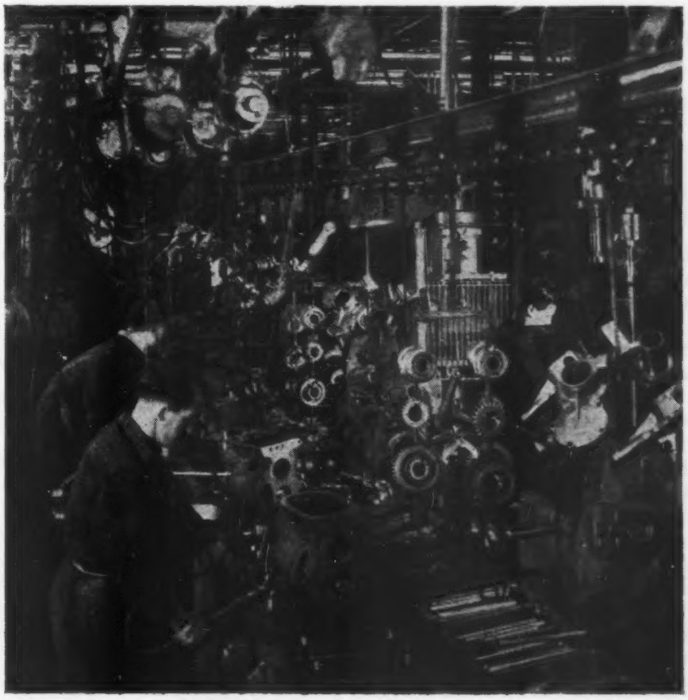


Fig. 3. An interesting example of overhead slung gear. *Courtesy Vauxhall Motors Ltd.*

Fig. 4. Temporary mezzanine for the local expansion of production and light storage.
Courtesy C. & J. Clark Ltd.

plant should receive specific consideration. An impression one gets on visiting many American factories is that changes are made frequently in medium and large-sized organisations. Whether sensitivity is so high among British firms is impossible to say, but much movement undoubtedly goes on and seems to be increasing.

It is likely that willingness to consider change depends partly on the ease with which it can be done, for the more difficult it is, the bigger the case that must be made out for it, even in one's own mind. Essentially there are three points to consider:

(a) connection to the floor;
(b) disconnection and reconnection of services;
(c) the movement itself.

The last of these has many well-known tools to assist it, and most of them have nothing to do with the building. The other two belong to this discussion.

The first question is whether or not to fix firmly to the floor. The resilient mountings now available keep machines steady without firm fixings, and the attraction of not having to cut into the floor to fix and unfix is considerable. Quite apart from anything else, the repair is likely to be a place which will begin to wear quickly.

The disconnection and reconnection of services and wastes is another matter that seems to have had no specific study. Occasional examples of simplified arrangements are to be found, especially for electrical supplies, but further systematisation should be made.

As regards the actual movement of plant, the single-storey factory seems to present no particular problems except for the familiar links between very heavy plant and the overhead cranes which are necessary to move it, and the types of floor structure or foundations necessary to permit the changes. In multi-storey factories, however, important difficulties may arise and as with the movement of fork-trucks, a systematic view must be taken. The floors must be capable of carrying the loads in transit and receiving them without special construction work, and the methods likely to be needed in passing them from floor to floor must be thought out properly. In one recently-built factory a hole had to be made in the wall of the third storey to let in some new plant, floors had to be propped up along its route (with much disturbance of work) and a special floor had to be built to receive the new equipment; yet none of it was of very unusual weight or size.

processing aids and the removal of wastes

Processing aids and the removal of wastes will be linked in this discussion to encourage consideration of them as related systems. The matter is visualised this way; there are usually materials circulating on which work is to be done; the work usually requires a supply of power and possibly liquids or gases as processing aids; and a by-product of the work is a certain amount of solid, liquid, or air-borne waste which must be removed — and perhaps it too must have some work done upon it before its final discharge.

Electric power is one of the fundamental processing aids. The amount available depends on the amount for which provision has been made in the supply and control gear and on what the internal circuits will carry. When the limits of these are reached, major changes are necessary in the supply equipment before expansion of production can take place. The electrical installation generally costs from 1/10th - 1/5th of the whole cost of a factory and it is therefore not an item which invites substantial renewal frequently. It should be planned at the outset for expansion on a long-term forecast. In principle the sound course will generally be to make the main sub-station big enough structurally to handle all likely needs, and then — if the factory is large

enough — to zone it as a whole into a series of load-areas, each with its own unit sub-station. The system can then be expanded easily by increasing the main sub-station capacity and adding more load-areas without interfering with those already in use. The unit sub-stations should be as near the centre of gravity of each load-area as practicable, and this points to a merit of the mezzanines that are discussed elsewhere. Internal sub-stations may make necessary transformers of a type having reduced fire risk, but there are off-setting economies.

In multi-storey factories it is possible that a single load-area circuit in a ceiling could serve the floor above conveniently.

Other processing aids — liquids and gases — have not been the subject of detailed studies at the Station, nor anywhere else known to the author. It seems quite likely that they would reward an investigation leading to a systematic view of provisions likely to be needed in factories. But the essential matter is to forecast needs as far ahead as practicable, and to make provision for the vital items of equipment on an appropriate scale, even if their full capacity is not installed or utilised for some time to come. The installation itself should be organised so that its replacement does not require serious structural alterations.

Waste removal and treatment resists generalisation, but it presents numerous potential embarassments for the future which call for the most careful forethought possible.

No real difficulties arise about wastes which only require trolleys of some kind for removal. The removal of dusts is not very difficult either, since they can be sucked into tube systems and generally go out overhead.

Scrap which calls for conveyors to remove it can be somewhat more awkward because of the way these can interfere with the use of floor space, and because eventually they usually have to be taken out overhead or dropped below the floor to get to a processing point. Attempts have been made to anticipate future demands sometimes by underground duct systems, and where these are built they are usually for other purposes such as dust ducts and piping of various kinds. They are expensive however and their location is fixed and sometimes access is difficult; the chance of recovering on them is perhaps problematical. Removal by fast-running water in channels is another method on which the same comment can be made.

It seems that unless a basement has to be provided for other purposes, underground waste removal is likely to be limited to particular rather than general solutions. This suggests that overhead removal is a technique that will have to be increasingly developed and it is interesting that installations of this kind for removing both liquid and solid wastes have begun to be used in the U.S.A. Considerable pumping capacity is needed for liquids, and the pumps must often be of special types to deal with chemical wastes; but this is far less expensive than ploughing up floors and is a great deal more flexible. Vertical screw conveyors leading to horizontal carriers have been used for swarf and scrap solids and this again gives valuable flexibility. It seems that one could say as a generalisation that services and wastes should be all together, either above or below, and not divided.

structural factors

The spans, the height and the load-bearing capacity of the factory structure all have parts to play in respect of production.

Spans — The problem in choosing spans is to ensure that the floor space is not interrupted so frequently by stanchions that it becomes difficult to lay out plant economically, for this can cut down the utilisation of floor space and prejudice production efficiency. No studies appear ever to have been made which lead to clear recommendations, but it will be evident in principle that spans and the scale of the plant are related and also the degree of flexibility required. If plant is likely to be a multiplicity of independent small items, then relatively small spans are not likely to interfere very much, while if the plant is generally large on plan with its parts interconnected intimately, then relatively large spans would be needed if there is to be reasonable freedom for layouts and not too much wastage of space. Plant which comprises a mixture of small and large items, not too closely interconnected, ought not to find moderate spans too troublesome.

Spans are related to the cost of the structure and for single-storey factories they commonly pass through an optimum somewhere between 20 ft. and 40 ft. For multi-storey factories the corresponding figures would be of the order of 15 ft. - 30 ft. Increases of span do not usually result in sharp rises of cost, but the steepness of the rise generally goes up as the spans increase. Managements of course tend to believe the ideal is to have no vertical supports, but in practice they usually temper their approach with an eye to the cost of the structure. The optimum spans mentioned are generally below what managements today would regard as acceptable, but it seems that figures of 40 ft. - 60 ft. have given satisfaction for a wide range of industry, although managements have often asked for higher figures. It is quite often the case that framing systems are more economical on a rectangular bay layout with short spans in one direction and long spans in the other than with equal spans each way, though developments in methods of construction may alter this and production engineers often prefer the square bays. The rectangular bay is sometimes adopted in order to get large spans in at least one direction at reasonable cost; but it has to be remembered that they do not allow much overhead loading unless they are robust, and then the economy is offset.

Heights — Views about heights are more sharply drawn; 12 ft. - 15 ft. (floor to bottom of truss or beams) has been quite common in this country and still is. American engineers have held the view for a quarter of a century that the minimum should be 18 ft. or more, because of advantages it gives for overhead plant and communication, for storage, for mezzanines and for good air movement. Experienced

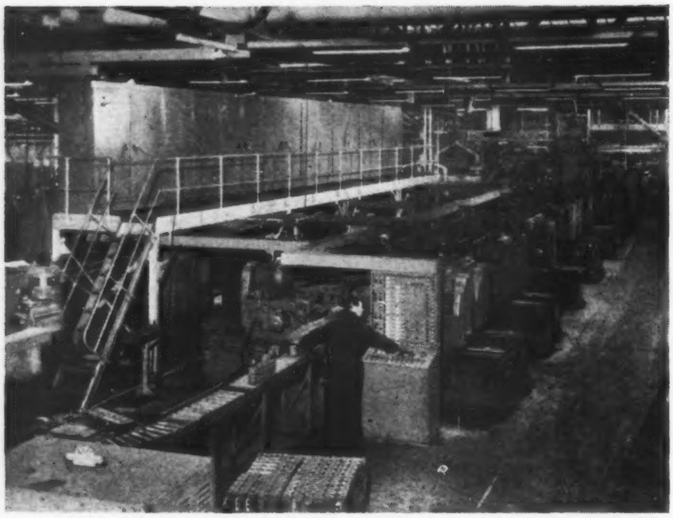


Fig. 5. Mezzanine development for power in connection with plant.

British designers have shared this view for some time, and have drawn attention to the paradoxical point that while managements here have tended to ask for relatively large spans on rather imprecise arguments and at appreciably higher costs, they have resisted greater heights for which clear arguments can be advanced and for which the cost is relatively low. At the same time the large spans have prejudiced overhead carrying capacity.

Insofar as plant is concerned, it seems to designers that there is an increasing tendency to develop in more depth, both with higher plant standing on the floor, and more plant suspended from above. Overhead conveyors are common, for example, either moving products from one place to another in the production layout, or simply killing time for products which are cooling or setting and which would otherwise occupy floor space more valuable for production. Welding gear and infra-red heating plant are often hung from above, and no doubt production engineers will know of many more such things than does the author.

Overhead walkways are sometimes desirable to facilitate the movement of supervising staff, or visitors, or for access to piping, or to connect with mezzanine level locker rooms, toilet and other accommodation, or to reduce congestion and disturbance of work in shift changing.

The modern fork-truck and other stacking plant make possible very high storage, and in the course of the life of the factory, the stacks might be needed in many places. Some American factories have been built with clear heights as great as 36 ft. to give freedom for this purpose.

A particularly critical height is this figure of 18 ft. At less than this it is not practicable to insert mezzanines, and these are increasingly popular not only for toilets and lockers but for office accommodation, for transformers, and for the local expansion of production space, especially on a temporary basis. This last use is unusual, but has been used with great success in at least one case known to the Station. Several of these functions call for accommodation close to or actually in the production area, but to have them located on the working floor itself could interfere undesirably with plant layout and productive work.

The advantage of height for good air movement is evident in a general sense but cannot be pinned down to exact figures. It does not bear directly on the relation between production and factory design and will therefore not be considered further here, except to say that it gives some protection against discomfort in hot weather, and when forced air systems are used, either for cooling or heating, the height enables the air-streams to diffuse before reaching working level.

The load-bearing capacity of the structure has to be considered in order to carry any suspended plant, and for this reason production engineers should be in a position to indicate the types of load and plant which might reasonably be called for in their types of industry, so that designers can make the necessary provision. In multi-storey factories, of course, the floor structure will have to take both the supported loads above and the loads hung beneath. A considerable amount of data about this matter is given in the Station's Factory Building Studies.

The simple facts of the matter are seemingly these: that the upper space is the proper location for service equipment, that heights between 12 ft. and 18 ft. offer the worst of both worlds, and that the choice of height, for good or ill, is final.

air control

One of the evident trends today is towards products and plant which require some form of air conditioning. Leather goods, textiles, finely machined parts, battery manufacture, transistors, cabinet work, colour printing, products where cleanliness is vital, food, plastics, surgical goods, and electronic control

of computer gear are all examples of manufactures or machines which now require control of air temperature, moisture-content or dust, either singly or in combination. There is also increased heat from plant to be taken care of. Factories which have had no provision for air treatment hitherto have often had to put in suitable plant, sometimes at much inconvenience. It is not reasonable to suggest that all factories should have air conditioning systems from the outset, but it is fair to say that managements should generally ensure that systems can readily be installed in the factories they build. Sometimes it will be needed for only part of the working area and it should be possible to isolate such a space; other times a system may be asked only to do heating at first, with the possibility that other forms of conditioning will be required later. Provision for such adaptation can be made from the outset.

There is little doubt that control of the air in a factory is proving to be one of the major factors in production to modern standards, and that to have, or be able to have it, easily is going to be an important element in keeping a factory modern through the years.

a state of well-being for operatives

The discussion of air control to meet production needs takes us naturally to the control of air and other environmental factors, light, colour and sound, to meet the needs of the operatives themselves.

While their effectiveness is to some extent simply a function of inborn ability and temperament and their general state of health, it is also responsive to the way they are managed and their sensory state. This last factor is subject to the influence of the factory through its effect upon the senses of vision, hearing and touch, and is therefore relevant to this discussion. It affects the ability to work quickly, safely and accurately.

Severe discomfort requires some effort on the part of the nervous system to fight off its consequences, and as a result there is some lowering of alertness in ways not fully understood but frequently enough observed, both clinically and personally. People generally will be familiar with the fact that when they are " chilled to the marrow " they react relatively slowly, and their control of hands and feet tends to be insensitive. Some firms have used warmed tool-kits to ensure quick sensitivity at the beginning of a shift. We are all aware that continuous noise at a high level is a strain, as evidenced by the sense of relief experienced when it stops; and of course in the presence of high general noise levels, the lesser noises that should often command an operative's attention because of information they give him about his work, or about things (sometimes dangerous) that are happening around him, are more difficult to hear and the significance he attaches to them is reduced. Exposure to prolonged noise levels above 95 db. also causes the onset of permanent hearing loss.

In the field of illumination, inadequate light and glare both give rise to some strain either through the struggle to resolve detail for which the lighting level is too low, or from sheer discomfort. Curiously, the loss of freshness and the onset of weariness due to bad lighting are often gradual and not linked by the subject to this or any other particular cause, unless the lighting is very evidently worrying him. It was commonly reported in America during the War, when fluorescent lighting in factories made practicable much higher levels than had previously prevailed, that work people were noticeably less tired at the end of a day than formerly. Similarly in this country, when higher standards of natural and artificial light were introduced in post-War schools, there were reports by teaching staff that children remained fresh to the end of the teaching day in place of sleepiness often encountered previously in the afternoon.

It has been difficult in experiments to examine or assess effects induced by sensory discomfort or disability, partly because of the capacity of the subjects to bring to bear reserves of energy in some form which can offset the effect, at least temporarily. The matter has begun to come under examination as a possible contributory cause of road accidents, and it has been suggested lately that while a driver can apparently drive very competently even when tired, he loses some of his ability to deal with emergencies in which he must assess and allow for several things happening simultaneously. It seems likely that something of the same sort is the case in factories and if so, it would be expected to reduce alertness generally, and through this to affect adversely quickness, accuracy and safety.

It is not possible to go farther than this on present evidence, except perhaps to observe that there is a measure of correlation between the results of exposure to severe conditions for a short time and exposure to less severe conditions for a longer time. In other words, a state of affairs that may not seem very unsatisfactory on casual observation may cause a substantial effect over the whole of a working day. Standards of criticism in assessing discomfort factors should be correspondingly high.

A special word is perhaps needed about colour. It should not be regarded as mere decoration in a factory, for it has several functions to perform. It may influence standards of care and attention to work, especially where cleanliness is concerned. It can play a part in carrying night shifts through the heavy hours of the early morning. Properly used, it has a direct and sometimes important contribution to make to comfortable and efficient vision. It can contribute to the general sense of well-being. But it must be well done; it is not a subject for amateurs if a good return is to be expected from the cost of painting. *Inter alia,* it must have the right character; one would not treat a steel mill as one would a cosmetic factory; but striking the correct character is a matter for experienced judgment. This is not a subject for a " do-it-yourself " approach.

It is neither possible nor necessary to review here the nature of good heating, lighting, colouring, ventilation or noise control. Some discussions are to be found in the literature and the Station's Factory Design studies will, it is hoped, prove to be useful additional references; perhaps especially the study

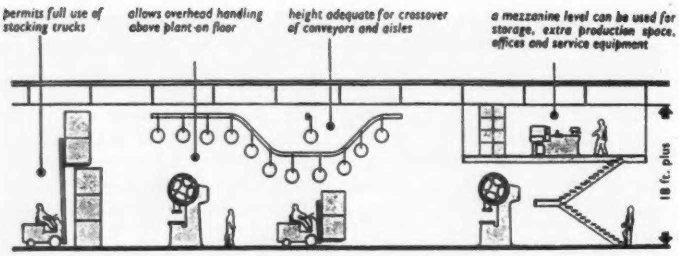


Fig. 6. A diagram of the uses of height in factories.

on Colour which is to be published shortly, because present references are inadequate. The one point which perhaps deserves emphasis here is that the recommended standards about comfort and discomfort in the literature are not merely intended to give pleasant working conditions, worthy though that motive may be. Their relevance is that they help to put operatives in a state of sensory well-being which contributes to their safety and effectiveness at their jobs.

fire protection

Regulations and bye-laws concerned with fire are framed chiefly to protect neighbouring property or to ensure the safety of the public and of employees, and not to protect the contents of a factory nor any other interest of the management. Conformity to regulations therefore will not necessarily protect a firm against the risk of being out of action for a damaging length of time.

Fire protection in a factory is made up of a series of planning provisions, of structural precautions, and alarms and extinguishing equipment. The protection required will usually consist of one or a combination of these methods scaled according to the size of the building, the nature and extent of its contents and the number of occupants.

In the development of a site, three particular factors call for consideration. Access roads must be suitable for fire-fighting equipment to get to all necessary positions, there must be adequate access to the interior of each building, and there must be space enough between buildings to limit the spread of fire.

In the general planning of the buildings there are certain fire risk relationships of which the developer should be wary. For example, where a single-storey structure lies beside a multi-storey structure there is an evident risk that fire in the former will break through the roof and attack the latter. Another example is an internal court in a multi-storey building; unless there is access to it for fire-fighting, it is an undesirable planning feature from this point of view. An internal court with a single-storey area filling its base might be a very unfortunate combination.

The most troublesome of all recommended fire-protection measures is sub-division of a building, for it is almost always in conflict with demands for freedom in production layout, automation, flow-line production methods, and so on. But it is an important form of protection for the firm, for it limits the spread of fire and smoke, and thereby reduces risks and increases safety. A form of sub-division is to locate the main stocks of combustibles, paint for example, outside the factory and pipe or convey them inward with automatic cut-off in case of fire.

It is evidently difficult to give explicit and detailed recommendations, and all that can firmly be said in fact is that sub-division into separate parts of reasonable size, which may run through from one storey to another, should be assiduously sought. For combustible goods and high-hazard processes, sub-division should of course be a primary consideration, even to the extent of using a separate building. Stairs and lift-shafts will always have to be enclosed to meet regulations.

Precautions that a firm should consider taking in its own interests should include the following: a sprinkler system, independent automatic alarm system, mobile fighting equipment, hydrants, hoses, ensured supplies of water and dry risers. Appreciable areas of linings that may spread flame rapidly should be avoided. Consultation with the local fire services is advisable at an early stage.

conclusion

The major factors in the design of industrial buildings which have a bearing on production have been considered. The discussion has not attempted to deal with any matter in detail, but to pick out principles by which the main outlines of an otherwise complex pattern can be seen more clearly.

Designers generally have experienced difficulty in obtaining from managements a statement of requirements which is both comprehensive and in their view sufficiently far-sighted to ensure a sound investment, judged by the ability of the building to accommodate changing requirements for production. The purposes of this Paper then are simply these; to identify the aspects of design which appear to contribute significantly to conditions for efficient production, and to emphasise the importance of stating the requirements not in terms of immediate needs, but probable trends.

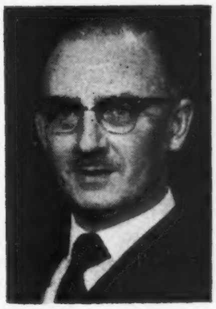
acknowledgment

This Paper is based largely on results of the research programme of the Building Research Station and is published by permission of the Director of Building Research.

Improving the Productive Efficiency of

ELECTRIC RESISTANCE WELD TUBE MILLS

A Thesis by E. J. SWINN, A.M.I.Prod.E.



Area Manager,
Wickman Limited,
Nottingham.

IN view of the fact that the process of electric resistance welding of steel tubing is confined to a relatively small number of factories in the United Kingdom, a brief description is appropriate as an introduction to the problem considered in this Thesis.

The process consists of a series of interconnected functions so arranged that strip steel in coil form can be converted into circular tubing on a continuous basis with the minimum cost. Basically these functions are: uncoiling, edge trimming, tube forming, welding, flash trimming, cooling, sizing and cutting off to lengths suitable for shipment or subsequent processes (see Fig. 1, which is based on a similar diagram used by The Yoder Company, Cleveland, Ohio, U.S.A., in some of their earlier publications).

The plant for carrying out this work comprises six or more machines or units set up in line at appropriate distances to form a complete tube mill, through which the strip is passed continuously and turned into tubing. Such a mill installation is shown in Fig. 2.

the cause of the problem

The problem of efficiency may arise in any tube mill installation, but in the writer's experience it is normally much more acute when a tube mill is installed for the first time in a company with no previous experience of this process.

For example, a company making any product which incorporates tubing in a substantial amount may decide that they can make the tubing themselves, cheaper than they can buy it from a tube manufacturer.

In this case they will apply to one or more of the suppliers of electric weld tube mills for a proposal and assuming they are satisfied on the economic advantage of making their own tubing, will usually buy a basic tube mill installation as described above. The supplier will usually promise an efficiency of 75% and say that with certain extra equipment which some users provide for themselves this efficiency can be improved to almost 100%. However, it has been the writer's experience that insufficient attention is paid to this point at the outset by either the supplier or the customer, with the result that a problem of low efficiency almost invariably arises soon after installation.

the problem

A firm which has recently installed a new electric resistance weld tube mill with the expectation of running at an efficiency of 75% - 95% is faced with the fact that the yield of tubing is only 50% of the optimum output of such a mill.

This may appear somewhat surprising, but it is by no means a hypothetical case. It is more the normal than the exception in the circumstances outlined.

Furthermore, the process being new to the user is shrouded with a certain mystery which obscures the reasons for the low efficiency, and tends to prevent

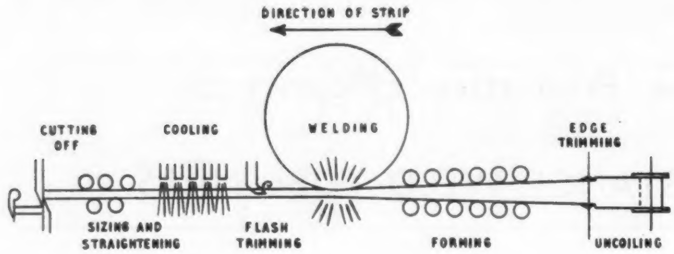


Fig. 1. Diagrammatic representation of tube making process by electric weld tube mill.

a procedure of investigation on conventional production engineering lines.

attacking the problem

The initial examination should be directed at the technical aspects of the operation to ensure that the correct process conditions obtain. This should be done in conjunction with the mill manufacturers, and the necessary corrections made before any attempt is made to alter or modify the overall installation.

The most important technical questions for checking are:

1. Is the steel being used to the correct specification ?
2. Is the strip free from rust, scale and damage ?
3. Are the welding edges properly prepared ?
4. Is the tube being formed to correct shape before entering the welder ?
5. Are the welding temperature and the electrode pressure correct ?
6. Does the seam maintain a straight line ?
7. When the tube arrives at the sizing unit, has the weld scarf been properly removed and is the tube cool enough to avoid unnecessary distortion ?
8. Are the cutters sharp in the cut-off machine ?
9. Do the tubes arrive at the dumping table in a sufficiently straight condition to avoid buckling ?
10. Is the mill running at the correct speed ?

Only when the correct answers have been given to these questions, and any discrepancies corrected, is it practical to examine the more general question of overall efficiency.

While it is important to clear these items first, it is usual to find the technical conditions are substantially

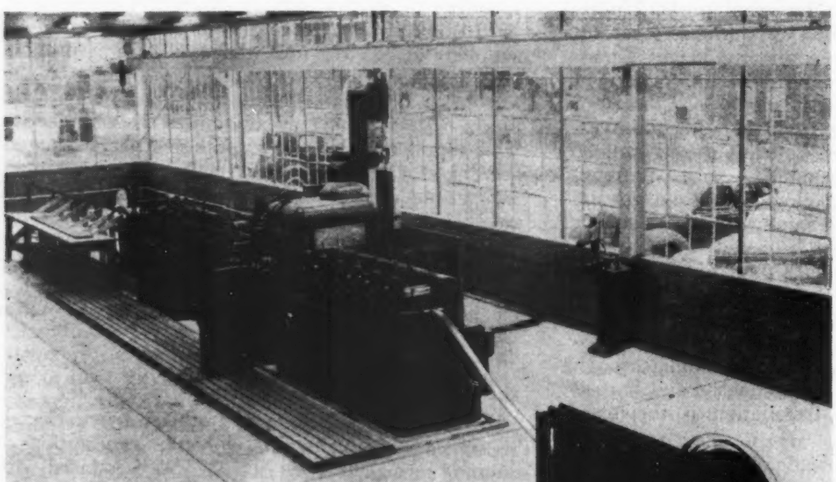


Fig. 2. Complete mill installation.

(Courtesy of The Yoder Company)

correct and that the main causes of inefficiency lie elsewhere. However, these correct conditions may not all be maintained during normal working over a period. Thus a detailed work study should be undertaken.

work study and analysis

This study should be in charge of one person and cover a substantial period of operation. While in some cases a full day's run may be sufficient, it is preferable to continue the study for several days to ensure that all the relevant factors are being covered.

It is essential to use a stop-watch and to record exact times of working at normal speed, and to establish at the same time the duration and cause of all stoppages and changes in operating speed. An exact record must also be kept of the quantity of tubing produced and the proportion of scrap.

The most important factors to watch for are as follows:

1. Initial starting time. Are the operators ready at the appropriate time and is the raw material (coil strip) in position or is there a delay in obtaining it from the stores ?
2. Are the consumable tools in good condition or is a start made with tools which will require reconditioning in the immediate future ? Do delays occur through operators having to wait for reconditioned tools ?
3. Check the mill speed immediately upon starting up and periodically during operation to establish whether slowing down occurs.
4. How often and for how long is the mill stopped to change the weld flash trimming tool, which has a relatively short life ?
5. Record all stoppages for adjustments and the reasons why they are necessary.
6. Establish exactly the time taken to start each new coil of strip and any footage of tubing lost through not being welded during each restarting.
7. The mill may be stopped for periods while the chief operator attends to personal needs, unless fully trained relief operators are available.
8. The mill may be stopped due to the inspector not passing certain lengths of tubing. Record the duration of all such lost time, the exact reason for the substandard tubing and what was done to re-establish correct production.
9. Whenever adjustment has to be made to welding current, check whether this is necessitated due to power loss caused by external equipment being switched on for adjacent processes.

When a complete record has been made, it is necessary to study the reasons for all interruptions to continuous production and to make an analysis.

Such an analysis will show clearly which parts of the process are causing inefficiency and thus where modifications have to be made to effect the necessary improvement.

The writer's experience has been that such an analysis usually follows a certain pattern and a fair example is given below:

Cause of stoppage	*% of production time lost*
Adjustments due to technical faults	6%
Scrap losses	4%
Changing weld flash trimming tool	8%
Operator and service delays ...	5%
Starting new coils, including initial starting on each shift	26%
Other contingencies	1%
	50%

In case it is thought that the 26% lost through starting new coils is rather astounding and should have been obvious from the start, it should be stated that this has not proved to be the case in practice.

The coil size of suitable strip steel normally available from steel mills in this country contains approximately 1,000 ft. of strip. Since the operating speed of modern electric weld tube mills is in the region of 100 ft. per minute *, it will be seen that a single coil of strip will take only 10 minutes to run through the mill before the coil is expended.

Thus in a case where the efficiency is only 50% there must be an equal period of 10 minutes lost in down time for every coil run. It may well take 5.2 minutes to mount another coil, thread it through the tube mill, restart the mill and re-establish production at 100 ft. per minute. It will be seen that this 5.2 minutes coil changing time recurs every 20 minutes, representing 26%.

However, once the analysis is made it shows very clearly that this item is a first choice for further attention in any effort to improve the overall efficiency. This and the other items are discussed under the following heading:

effective solutions

Considering first the question of reducing the time lost in starting new coils, there are a number of possible solutions. Theoretically, the most complete answer is to arrange for a continuous supply of steel strip to the mill and this can be done by end welding the last end of one coil to the first end of the next coil. To do this without stopping the mill necessitates the formation of a loop of strip immediately in front of the entry side of the mill.

This loop must contain a sufficient length of strip to feed the mill during the end welding process. Although the time taken to feed a new coil was found to be 5.2 minutes, in the case cited it will not be necessary to reckon on the whole of this time for end welding since the operation is changed. It will now be necessary to cut off the ends of the two following

* It should be noted that new techniques and welding processes are continually increasing the overall speed of operation.

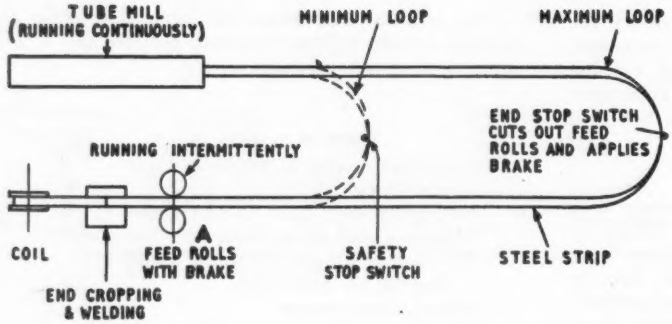


Fig. 3. Diagram of typical looping pit — plan view.

coils, squarely across, as a preparation, and to remove any damaged portions so that they may be joined by welding.

The cutting off may conveniently be done by a simple hand operated shear which is readily obtainable as an inexpensive proprietary unit. The welding may be done by a hand operated torch using oxy-acetylene gas, by argon arc welding or by electric butt welding. Again such equipment is relatively inexpensive and readily obtainable.

To finish this joint it is desirable to remove any excess weld flash, and this is normally done with a portable grinder or simply by hammering down the weld by hand.

Since the bulk production is normally in tubing sizes from $\frac{5}{8}$ in. diameter to $1\frac{1}{2}$ in. diameter and in gauges from .036 in. thick to .062 in. thick the equipment described is quite adequate, though it must be pointed out that for larger sizes of tubes and heavier gauges, powered machines would be required.

This operation usually takes about 2 - 3 minutes, so that the reservoir of strip in the loop will have to be sufficient to feed the mill during this period. Thus, if the maximum mill speed is 100 ft. per minute, the loop must contain a minimum of 300 ft. of strip.

Furthermore, this loop has to be formed by drawing strip from the coil to form a spare loop in front of the mill entry position. One of the simplest means of arranging this is by forming a free loop on the floor, known as a looping pit. This is taken from steel mill practice and will be made clear by Fig. 3. It should be noted that the feed rolls 'A' are stationary during end welding, but immediately the joint is completed, they feed the strip out at a higher speed than that at which the mill is running, thus forming the maximum loop.

For most firms making tubing for their own use, however, this arrangement is not very convenient due to the considerable amount of extra floor space required. Thus a form of looping gallery is preferable, such as is shown in Fig. 4. This can either be arranged above the tube mill as shown or, alternatively, in a pit formed beneath the mill. In either case the extra space taken up by the loop is acceptable, as it does not necessitate any extension to the factory space but is almost wholly contained within the original mill area. By an examination of Figs. 3 and 4 it will be seen that the end welding can take place without stopping the mill. As soon as the strip is stopped for the end joining operation, the mill draws strip from the loop, which is thereby shortened until such time as the two ends are joined together and the strip is again released. As soon as the strip is released the loop is reformed by drawing strip from the newly joined coil, and so the reservoir of strip is regained ready for the next end joining operation. Naturally this has to be arranged with interlock switching and a safety device to ensure that in the event of the operator taking longer than the prescribed time to join the ends, the mill will automatically be brought to a standstill.

With such an arrangement the whole of the time taken for starting new coils is saved, since the mill is supplied with strip continuously at the correct rate. Thus, reverting to the earlier example, the 26% time loss due to starting new coils can be virtually eliminated.

This solution has some disadvantages under certain common operating conditions.

Where a variety of sizes of tubing is required and the mill has consequently to be changed over frequently to different widths and thicknesses of strip,

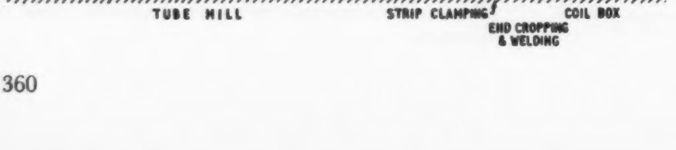


Fig. 4. Diagram of typical looping gallery — elevation.

it may prove that this arrangement is not as perfect as it would at first appear to be.

There are two main reasons for this. Firstly, such an arrangement is not easy to thread with a new size strip and the time taken to do this cannot always be overlapped within the minimum change-over time. Secondly, to ensure smooth operation on all sizes of strip within the capacity of the mill, certain elements have to be made adjustable and these are not very accessible. Thus the minimum change-over time may have to be extended to allow for this.

However, where long runs are possible on a single size of tubing, this solution is the most efficient.

Where more frequent changes are necessary in the size of tube produced, a more flexible arrangement for minimising the time taken for starting new coils may be desirable.

Several tube mill operators have solved this problem by building up their own large coils from the smaller coils supplied by the steel mills.

In most cases the arrangement is somewhat cumbersome, involving the use of several large reels which have to be positioned with a crane, in and out of the mill line. This method can be illustrated by describing an arrangement for utilising large coils which the writer considers offers the best solution, and which was developed by Walsall Conduits Ltd., West Bromwich (Fig. 5).

The small coils are simply placed on a steel floor over a retaining post and are fed to an end welding line consisting of a hand shear, welding bench and large twin reels. The large reel is arranged on a turntable in such a way that while one side of the reel feeds the tube mill, the twin reel on the other side is being used to build up a new coil. When this is done, the turntable is rotated, thus bringing the new reel into the tube mill line and the spent reel into position for refilling. The revolution of each reel is independent of the other.

The reel on the build up side is driven by an electric motor and reducing gear with clutch while the reel feeding the mill runs free, being rotated by the strip which is pulled by the traction of the rolls in the tube mill. Thus no problem of speed synchronisation is involved.

Each reel becomes alternatively driven and free running according to its position and this is readily accomplished by the use of the twin clutch.

Another feature of this design which adds to its flexibility is that the reels are arranged with spacers so that two or more coils can be built up adjacently on each reel. Normally these would be for the same strip width, but they can readily be adjusted for any alternative width of strip which may be necessary when changing over to another size coil.

The arrangement for revolving the turntable is simple and effective. It is arranged on a roller track let in the floor. No power is required and despite the weight of strip carried it is easy to rotate the twin reels by hand. Two locking positions are provided at

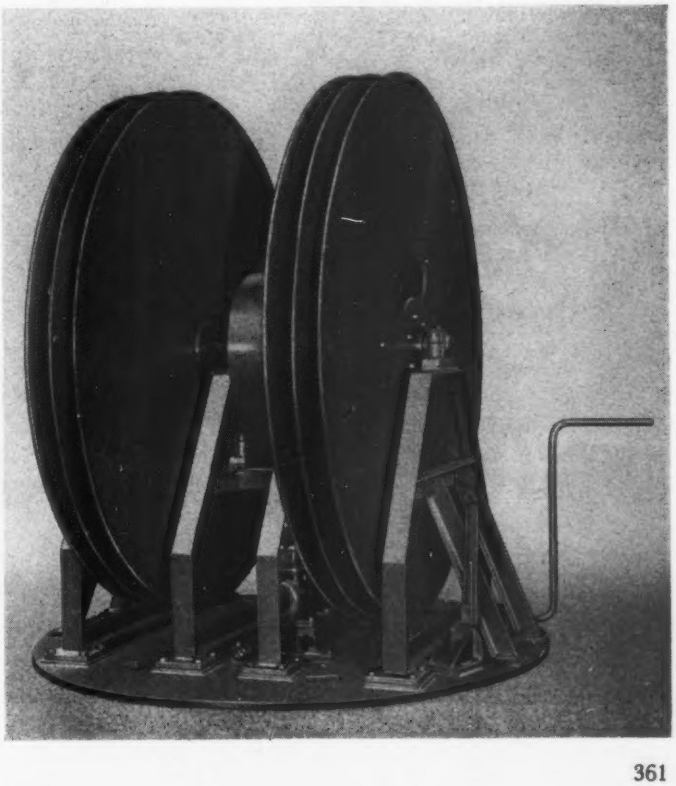


Fig. 5. Arrangement for utilising large coils.

180° so that there is no chance of their being swung out of line unintentionally.

The effect on the time saved by using the larger coils to feed the tube mill will be illustrated by the following example.

Coils of suitable strip as supplied by the steel mill contain approximately 1,000 ft. of strip. If 10 of these coils are joined together by end welding and built up into one large coil a continuous strip capacity of 10,000 ft. will be available. If a 10,000 ft. run of the tube mill fed with the small 1,000 ft. coils is compared with a similar run with the larger coil, we get the following figures:

Tube mill fed with ten 1,000 ft. coils

Time taken for feeding new coil and starting mill	=	5.2 minutes
Running time for first coil at 100 ft. per minute	=	10.0 minutes
The above operations must be repeated 10 times to produce 10,000 ft. of tubing, so that the total time is 10 (10 + 5.2) minutes	=	152 minutes

Tube mill fed with one 10,000 ft. coil

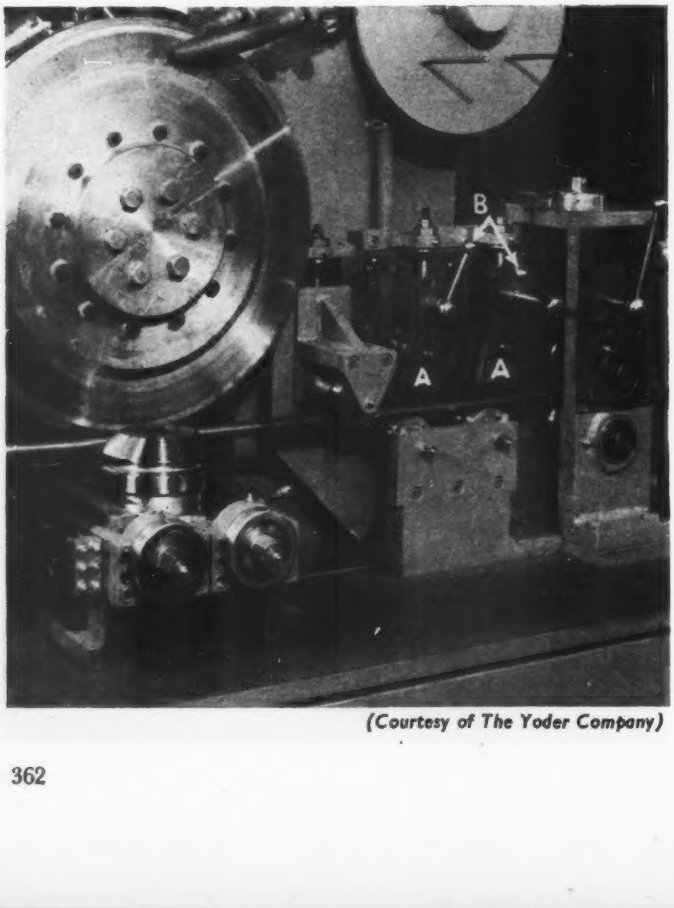
Time taken for feeding new coil and starting mill	=	5.2 minutes
Running time for 10,000 ft. of tubing at 100 ft. per minute	=	100 minutes
Thus total time	=	105.2 minutes

If we assume that no alteration has been made in any other function affecting the efficiency factor, there will still be a further period of time taken due to such losses, i.e., adjustment for technical faults, scrap losses, changing flash trimming tool, operator delays and contingencies. Based on the first example given, this would amount to a further 48 minutes for every 10,000 ft. of tubing produced when the mill is fed with the 1,000 ft. coils and somewhat less when using the large 10,000 ft. coil. The latter is due to the fact that the scrap loss with the larger coil would automatically be reduced. However, since the writer intends to deal with scrap losses as a separate item, and the present object is to show independently the effect of changing the coil size, it will be assumed that 48 minutes (or the equivalent loss of tube production) is the loss due to other causes of inefficiency, irrespective of whether 1,000 ft. coils or 10.000 ft. coils are run.

Thus the total time for producing 10,000 ft. of tubing will be 152 + 48 = 200 minutes when using the 1,000 ft. coils, and 105.2 + 48 = 153.2 minutes when using the 10,000 ft. coil.

Obviously, if the mill ran continuously at 100 ft. per minute for 10,000 ft. without any delays or loss of tubing, there would be 100% efficiency and the time taken would be 100 minutes. Transposing the figures in the above example, 200 minutes represents 50% efficiency and 153.2 minutes represents 65.27% efficiency.

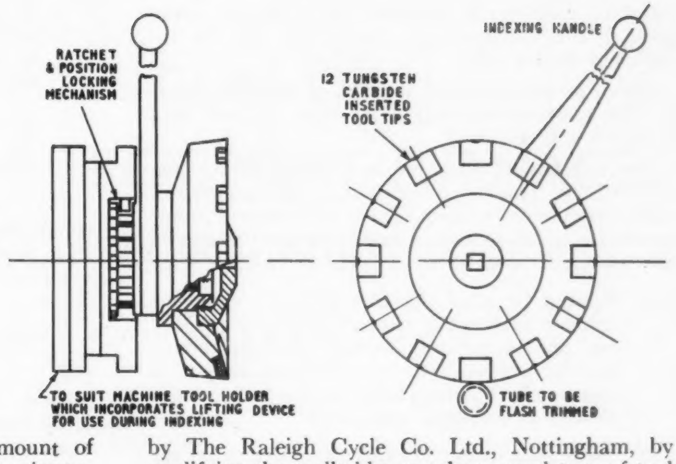
If instead of utilising the large 10,000 ft. coils the mill had been fed continuously by means of a



(Courtesy of The Yoder Company)

Fig. 6. Details of squeeze roll mounting; tandem flash remover and winder; ironing roll stand.

Fig. 7. Indexing flash trimming tool with multiple tips.



looping table or equivalent, the same amount of tubing would have been produced in 148 minutes, which represents 67.56% efficiency.

Consider now the next most serious cause of lost time found in the original analysis, i.e., changing the weld flash trimming tool. This tool cuts away the surplus metal thrown up on the outside of the tube as a welding flash or bead. It takes place immediately after welding, while the weld bead is still red hot, and thus is a very severe duty for any cutting tool.

It is modern practice to use a tool tipped with tungsten carbide but even so, the edge may become dull before 1,000 ft. of tubing has been produced.

To avoid scrap tubing this tool must be changed as soon as the cutting edge becomes dull and normally the mill must be stopped during this time. For this reason the analysis showed that 1.6 minutes were lost during each 1,000 ft. of tube production.

While the solution to this problem may seem obvious when it is pointed out, it is nevertheless true that it had not been solved until recent years. The solution is to change the tool without stopping the mill, and to do this without a considerable scrap loss it is necessary that a new tool be brought into operation almost simultaneously with the withdrawal of the used tool.

an effective solution

One effective solution has been found by The Yoder Company on their latest design tube mills. This makes use of a tandem toolholder arrangement as shown in Fig. 6.

Two identical flash trimming tools are mounted in the adjacent toolholders (A) which work independently. In the illustration the tool on the right-hand side is shown in position for trimming, while the left-hand tool is raised (by lever B) so that a new or resharpened trimming tool is held as a spare. When the first tool becomes blunt it is only necessary to raise it and at the same time lower the second tool into position. This can be done while the mill is running and without producing any tubing with untrimmed weld flash.

On an older design mill with only a single flash trimming tool, a solution to this problem was found by The Raleigh Cycle Co. Ltd., Nottingham, by modifying the toolholder to take a novel type of tool which they designed and made.

A sketch of this tool is shown in Fig. 7. It will be seen that the tool is similar to a face milling cutter. The circular body is provided with 12 inserted blades which are of tungsten carbide. Only one blade at a time is in contact with the tube. When this blade becomes blunt, another blade is brought into postion by rotating the body radially by means of a hand lever and ratchet mechanism.

By utilising one or other of these devices the time lost in changing the weld flash trimming tool is eliminated. This may well mean a saving of 8% lost production time as indicated in the original example given in the first part of the Thesis.

The next most serious cause of lost production time in the original example was due to adjustments due to technical faults.

From observation over many years the writer has found that the most important factors are normally either initial inexperience in running tube mills, or lack of technical information by the personnel in the factory responsible for running and maintaining the mill.

In the first case, improvements come with greater experience which, however, may take months to achieve, and in the second case additional technical information must be provided by management from the sources which are available to them.

It is a fact that with proper control and attention to detail, the production time lost due to technical faults can be reduced to about 1%.

The next item to which attention must be given is operation and service delays. While in the main this is a question of normal management and will be dealt with on conventional lines, it is important to realise that in most cases the running of a tube mill is foreign to many operators. They have to be specially trained if a high level of efficiency is to be expected. The ready accessibility of replacement tools and an efficient maintenance service, are most important. The requirements are specialised and too much reliance must not be placed on normal shop routines and

standard engineering practice which may be quite good in other departments, but which may be insufficient in this field.

Given proper attention, there is no need for delays in this category to total more than 2% of total production time.

Turning now to the question of scrap losses, these can often be reduced by normal production control and inspection techniques. There are, however, some particular points which should receive attention in the tube mill process:

1. Bearing in mind that the material is passing through such a mill continuously at say 100 ft. per minute, a large footage of scrap tubing can be produced in a very short time if a regular check is not made and the mill stopped as soon as a fault is discovered.

2. Weld flash is not normally removed from the inside of the tubing but it must be kept to a minimum. Since it is not readily visible, particular attention must be given to regular inspection.

3. The quality as regards outside weld flash removal must also be checked frequently, as any damage to the tungsten carbide tipped trimming tool will immediately affect the tube. In this connection the writer would point out that standard tool practice is not applicable. It has been found that when the normal grade is applied the life between tool changing is in the region of 1,000 ft. of tubing. With specially developed tools, however, this has been raised to 2,500 ft. per tool change (Reference — Wickman Ltd., Wimet Division, Coventry).

4. Weld quality is affected by many factors, but some which warrant particular attention are:
   - avoidance of inferior quality replacement electrodes;
   - maintaining correct form and gap on the electrodes by regular trimming;
   - squeeze roll concentricity;
   - maintaining even welding current and mill speed;
   - cleanliness and correct form of welding edges.

5. Checking quality of steel strip received, particularly during times of shortage and whenever an alternative supplier is used. Whereas for many production uses it does not matter whether the strip received has rim edges or has previously been slit from a wider strip, this fact is important in the tube mill process where the two edges must be welded together.

6. Any damage to only one of the many rolls employed in a tube mill may result in damage to the tubing, so that cleanliness and regular inspection of the mill is essential.

7. Some scrap loss is inevitable at the start of each new coil of strip material, so that it will be seen that the use of a looping gallery with continuous strip feed or the use of large built up coils gives an automatic reduction in the scrap loss.

8. Similarly, tubing is spoiled almost every time the mill is stopped, so that all unnecessary stopping and starting must be eliminated.

The foregoing points are by no means all those which affect this question, but are good examples of what to look for, and show that there is no necessity to put up with a high scrap loss. With proper attention the scrap loss may be reduced to at least 1%.

Finally, in the original example 1% production loss was given as due to other contingencies. This, it is felt, is normal and it is not proposed to modify it, since the writer has yet to experience the production process which is immune from an unexplained minor inefficiency.

A comparison of the original example (page 359) with the improved conditions obtained by adopting the solutions which have been recommended in this Thesis shows:

Cause of stoppage	*% of production time lost*	
	Original example	*Improved operation*
Adjustments due to technical faults	6%	1%
Scrap losses	4%	1%
Changing weld flash trimming tool	8%	Nil
Operator and service delays	5%	2%
Starting new coils including initial starting on each shift	26%	Nil*
Other contingencies ...	1%	1%
Total inefficiency	50%	5%

* This assumes the use of a looping pit or looping gallery. If the alternative solution of using large built up coils (containing 10,000 ft. of strip) is adopted, this item will be approximately 4.3% and the total inefficiency will be 9.3%.

It will be seen that by adopting the solutions recommended, it is quite possible to improve the overall efficiency from the original 50% to approximately 95% if a continuous looping arrangement is used or, alternatively, to approximately 90.7% if the large built up coils are used.

This is confirmed by the practical experience of some of the more efficient tube mill users.

conclusion

It is hoped that the writer has shown in this Thesis that the problem of improving the productive efficiency of electric resistance weld tube mills, although an unusual one, will nevertheless yield to the application of production engineering principles if applied with intelligence and patience.

THE EVOLUTION OF STOCK AND HEAT TREATMENT FURNACES FOR DROP FORGINGS

A Thesis by C. G. W. BETTS, A.M.I.Prod.E., A.R.Ae.S., A.M.I.E.T.

Night Manager,
Firth-Derihon Stampings Ltd.,
Darley Dale.

MAN is known to have heated metals for making into weapons and ornaments for the last 4,000 or 5,000 years. The craftsmen of Ancient Egypt and China appear to have attained great skill in metal working. As far as can be discovered, in this country charcoal and wood fires supplied with forced draught from bellows made from animal skins were what we might call the earliest type of forge heating in our industrial history.

As the use of wrought iron and steel became more general in the manufacture of knives, agricultural implements and weapons of war, the foundation was laid for the present forging industry. The first furnaces were just chambers of brick into which iron was put on a bed of burning wood, air being supplied either by natural draught or bellows. The next development was to place fuel at one end of the furnace chamber, and at the other end a chimney stack was built. The flames and heat were thus drawn through the length of the furnace, so keeping the furnace charge reasonably clear of the ashes and clinker. It was from such beginnings that the reverberatory furnace was evolved. This type of furnace was quite suitable for the fuels then available (wood and coal) with their high content of volatile matter. Furnace design was empirical and successful furnace operation was achieved by practical experiment only. Fuel economy was very much a thing of the future.

The subject matter of this Thesis is based largely on a recent reconstruction programme undertaken by the author's employers, The Firth-Derihon Stampings Limited.

Other organisations may have already encountered similar circumstances, and the related experiences may be of some assistance in resolving their problems.

2. the beginning of furnace technology

2.1 *availability of new fuels*

Up to the early part of the century the main fuels used were coal and coke. With intensive industrial development, there became available a selection of furnace fuels thus:

(a) coal
(b) pulverised fuel
(c) producer gas
(d) fuel oil
(e) town's gas
(f) electricity

(a) *Coal* is the cheapest fuel (see Table I) but its use is decreasing owing to the many disadvantages which outweigh the low cost, viz.: poor temperature uniformity and variable combustion efficiency, because of the varying amounts of secondary air required before and after coal feeds. Most coal-fired furnaces work on natural draught which makes temperature uniformity difficult to achieve. Waste heat recovery is also difficult due to ash in the waste gases.

TABLE I

Fuel	Cost/Therm
Hand-fired coal	5.2d.
Pulverised fuel	4.2d.
Producer gas	7.2d.
Fuel oil	6.6d.
Town gas	11.1d.
Electricity	31.2d.

(b) *Pulverised fuel.* This can be a highly efficient fuel for forging furnaces. The emissivity of the flame is high, but temperature uniformity, automatic temperature control and measurement are very difficult to achieve owing to the dirty nature of this heating medium. Waste heat recovery is very difficult as all the ash in the coal passes into the furnace chamber.

(c) *Producer gas.* This form of heating uses relatively cheap coal or coke while deriving some of the advantages of a gaseous fuel, viz.: easier control of temperature and temperature distribution, and also a positive furnace pressure can be maintained. However, the combustion efficiency is slightly lower than for town's gas. When continuous three-shift working is not in operation, starting up and standby losses may become excessive. Waste heat recovery is essential for reasonably fast and efficient working at forging temperatures.

(d) *Fuel oil.* This has a wide demand now in the steel industry as it has a lower cost/therm than town's gas, while temperature and temperature distribution are relatively easy to control. The fuel/air ratio can be controlled easily if no preheat is used, but becomes more difficult if waste heat recovery is required.

(e) *Town's gas.* This is the most adaptable fuel, but the dearest apart from electricity. Being a clean gas it is easily metered and is ideal for automatic control of temperature and fuel/air ratio and, therefore, requires only a minimum of attention. With suitable equipment it will give excellent temperature uniformity.

(f) *Electricity.* This is the dearest fuel in common use, but its main advantages are: a 100% conversion efficiency and that automatic control is easily effected, resulting in low labour costs.

2.2 modification of furnaces

As already mentioned, the crude form of furnaces in the 19th century was, at the best, of the reverberatory type.

By the early part of this century, furnace design was beginning to become a science rather than an empirical art. The urge for this came from an appreciation of the alternative fuels to coal which were also more expensive, and the war-time shortage of coal. As a result, the different ways in which heat is lost from a furnace were studied and modifications or improvements were made to reduce them to a minimum.

Some of the heat derived from burning a fuel in a furnace passes into the furnace charge and the remainder is lost in various ways, viz.:

1. the heat in the products of combustion leaving the furnace;
2. heat passing through the furnace lining into the atmosphere;
3. to heat up the lining.

The heat in the waste products was the first item to receive attention when Siemens developed the regenerative open hearth furnace. By recovering some of the heat in the waste gases and transferring it to the air and/or gas, the heat input per unit quantity of fuel burned was increased, resulting in a higher flame temperature and a lower temperature of the gases entering the chimney. Some idea of the economies due to preheating the combustion air is given by comparing the curves in Figs. 1 and 2, where:

$$\text{Combustion efficiency} = 100\left[\frac{1 - \text{Heat in waste gases}}{\text{Heat input}}\right]\%$$

The fuel consumption required is inversely proportional to the combustion efficiency.

Waste heat recovery by means of recuperators was later developed. A third development in waste heat recovery was the preheating of stock in a separate chamber heated only by waste gases from an adjoining high temperature chamber (Fig. 3). By this means the combustion efficiency is increased, since the heat in the waste gases in the preceding equation now refers to the products leaving the preheating chamber, which is at a lower temperature. When the preheated stock is transferred to the high temperature chamber, less heat is required to bring it to the

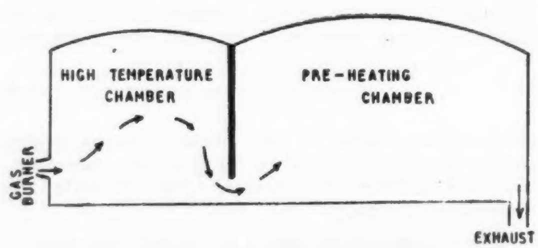


Fig. 3. Use of waste gas for preheating stock.

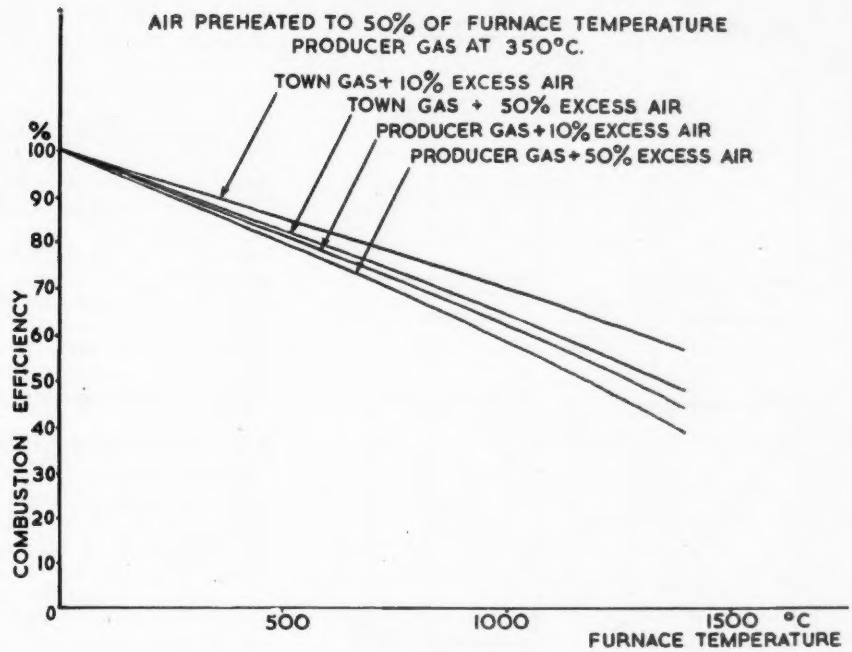


Fig. 1.

required temperature and a higher output is obtained.

The foregoing developments reduced the heat loss in the waste gas by extracting further useful heat and reducing the temperature of the gases leaving the furnace. Another way to reduce this heat loss is by keeping the waste gas volume down to a minimum by admitting only sufficient air to burn the fuel supplied to the furnace. Any excess air has to be heated up and leaves the furnace somewhat above the furnace temperature. The effect of using 10% to 50% excess air when burning town's gas or producer gas is shown in Figs. 1 and 2.

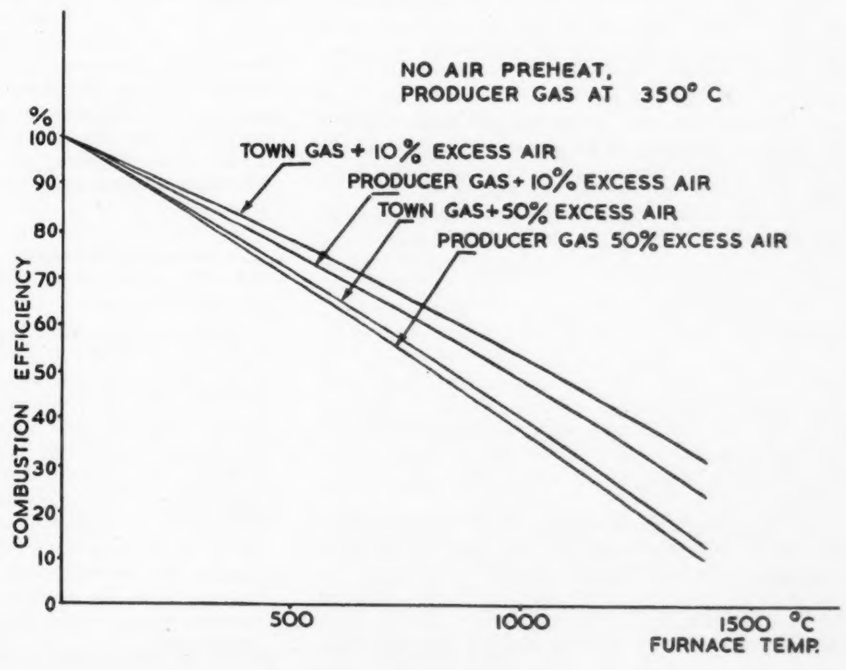


Fig. 2.

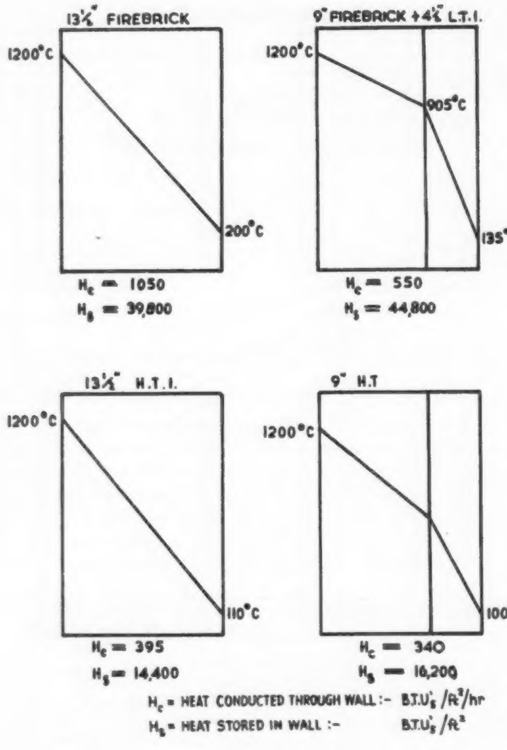


Fig. 4.

The early furnaces, fired by solid fuel or natural draught burners, required the furnace to be operated under a suction, so that cold air was drawn in at any gap in the furnace structure. The development of forced or balanced draught for solid fuels and two pipe burners with fan air for gaseous fuels, allowed the furnace chambers to be pressurised sufficiently to eliminate air infiltration and improve both temperature uniformity and combustion efficiency.

In recent years, rapid strides have been made in developing instruments for the measurement and control of air and gas flows, fuel/air ratio and furnace pressure.

The second item of heat loss — that conducted through the furnace structure — was first reduced by building very thick walls. The discovery of diatomaceous earth, and its subsequent manufacture into bricks, made a large reduction in this conducted heat possible with thinner walls, as shown in Fig. 4. As this material is not stable above 900°C, it is placed behind firebrick in the cooler part of the furnace wall.

Although primarily developed for their light weight for use in portable furnaces, the high temperature insulating refractories have proved very useful for reducing the third item of heat loss — that required to heat up the furnace lining. Their thermal conductivity and density are intermediate between those of firebrick and low temperature insulation, such as diatomite, but their refractory properties allow them to be used at the inner, hot face of a furnace wall in place of firebrick. As Fig. 4 shows, the amount of heat conducted through a wall is less than for firebrick and, in addition, the quantity of heat stored under "steady state conditions" is much less than for firebrick or firebrick with diatomaceous insulation. This results in faster heating-up times or reduced fuel consumption or a combination of both, especially for intermittently operated furnaces. With furnaces operating for long periods at steady temperatures, the heat conducted through the lining becomes more important than the heat stored in it, and so firebrick at the inner face with high and/or low temperature insulation behind it would be better because of the longer life of the denser firebrick.

2.3 *simple pyrometric control*

The first attempts at furnace temperature measurement made use of cones of materials of definite melting points. Three of these cones were placed in the furnace in a position where they could be observed through a peep-hole in the side or door of the furnace. When the cones began to melt, the furnaceman stabilised the furnace at this temperature as well as he could.

The development of the thermocouple allowed continuous measurement of temperature. Many types of couple have been introduced, but in the steel industry the platinum, platinum 13% rhodium and the base metal (chromel, alumel) couples are used almost exclusively.

The first indicators used were of the galvanometer type, from which recorders and controllers of the chopper bar and self-balancing potentiometer types were developed. However, no instrument with a sensitive galvanometer movement can be expected to maintain its accuracy in a drop forging works, due to the excessive vibration, without considerable maintenance or elaborate mountings to minimise transmission of the vibrations to the instrument. For use under these conditions the recent introduction of the electronic temperature recorder has been a big step forward.

3. present day standards of furnace technology

3.1 *the increasing complexity in the demands on forgings*

Before the last War, drop forgings were designed with a large factor of safety, using well-known steels with sufficient alloy content to make forging and heat treatment a relatively simple affair by modern standards. During the War the shortage of alloys, particularly nickel and molybdenum, necessitated the introduction of the E.N. series of steel specifications, using other alloying elements to replace nickel and molybdenum wherever possible. Higher power/weight ratios were required in the development of piston engines for aircraft, and since the War this trend has spread to the automobile industry where higher strength/weight ratios have been sought for many components.

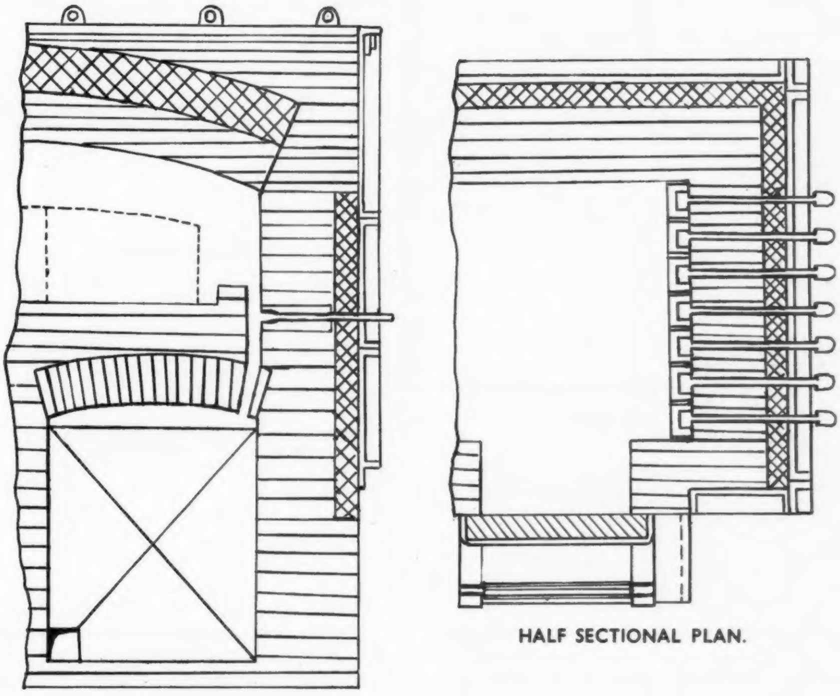


Fig. 5. General arrangement of producer gas fired furnace.

The development of the gas turbine has added impetus to the development of steels with high creep strength, whilst heat-resisting and stainless steels have also been developed rapidly in recent years. These developments have made greater demands on the equipment needed for forging and heat treatment. The permissible temperature range in which forging may be carried out is much narrower for most of the newer highly alloyed steels than for the low alloy and carbon steels. In addition, heating rates must be closely controlled to prevent internal cracking. After forging, the final heat treatment requires greater accuracy if the desired mechanical properties are to be obtained.

The furnace equipment required for the drop forging industry today must, therefore, give accurate control of heating and temperature, with good temperature uniformity in both reheating and heat treatment furnaces. At the same time the furnaces should be efficient to keep costs down to a minimum while obtaining a satisfactory product.

3.2 furnace design

3.2.1 *introduction*

This is too wide a field to cover completely in this present Thesis, and so has been limited to the particular application at the author's works.

3.2.2 *original furnace plant*

This plant was erected in a rural area in line with the policy of decentralisation during the last War. No town gas was available, and oil was in short supply at this period, so the choice of fuel was either hand-fired coal or producer gas. The latter was chosen as it gave better control and uniformity of heating. The gas was made from coke, thus eliminating the problem caused through tar when making producer gas from coal.

The forgings made at these works are in a wide variety of shapes and of different alloy steels, therefore batch type furnaces were installed. These were of the reversing regenerative type (Fig. 5), the air only being preheated. Separate valves controlled the air and gas which meant that the combustion efficiency depended largely on the furnacemen. Each furnace had an air fan, and an exhaust draught fan driven by the same electric motor.

The furnaces were constructed of firebrick with low temperature insulation over the roof. Three different furnace sizes catered for the large variation in workpiece sizes.

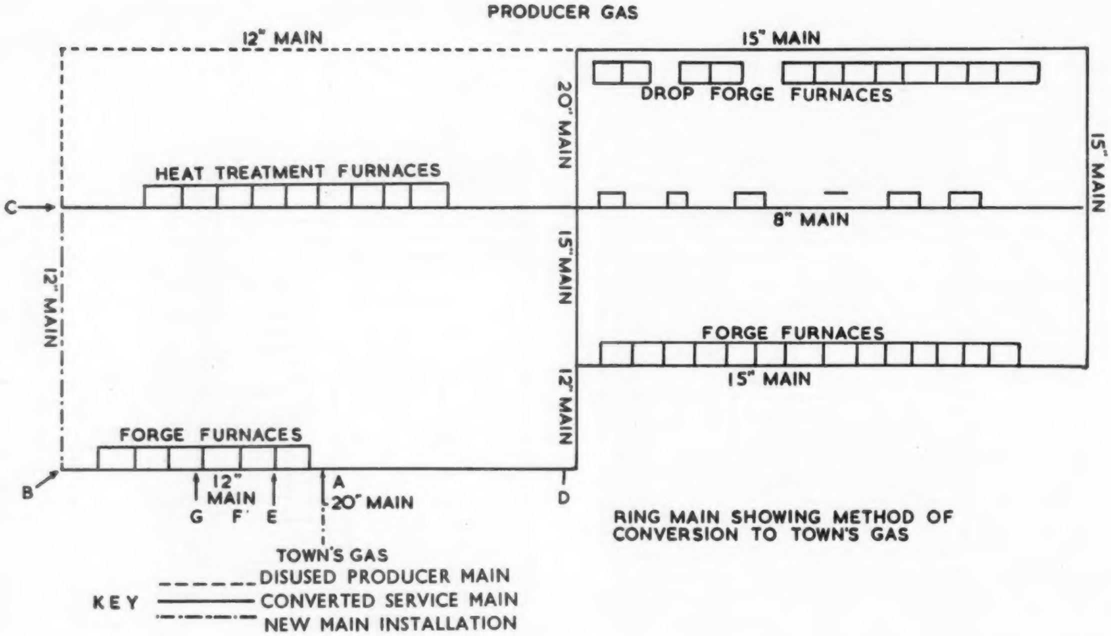


Fig. 6.

The 26 heat treatment furnaces were direct-fired, with eight burners on each side, exhausting through ports in the door vestibule. The furnaces were manually controlled and temperature uniformity depended upon the manipulation of 16 gas burner cocks. The construction was of firebrick with insulation on the roof only.

The loading of all furnaces was done by hand with some assistance from overhead monorails carrying block and tackle on the larger stamps. The interdepartmental transport of forgings is done by electric truck and overhead cranes.

Pyrometric control of the forge furnaces consisted of a thermocouple inserted under the door of the furnace and coupled to a galvanometer type temperature indicator. In the heat treatment department, thermocouples were inserted through the roof of the furnace and were connected to galvanometer type recorders.

By 1955 it was becoming apparent that the equipment described was inadequate in several respects for the type and quality of work carried out, and a programme of modernisation was begun.

3.2.3 *choice of fuels*

The first decision to be made concerned the type of fuel to be used. The following were discarded:

Solid fuel — because of lack of adequate control.

Dirty gases — for the same reason, unless cleaned at extra cost which was not justified in view of the rising maintenance costs on the present generating plant.

Induction heating — due to the short runs, varying billet sizes, necessity for intermediate heating of some jobs, the numbers of coils required would have been excessive and more than one frequency would have been needed, making the initial capital costs of motor generator sets excessive.

This left the choice between town's gas and fuel oil. Town's gas was chosen for the following reasons:

(a) previous experience in another works was available ;
(b) greater ease of control and distribution ;
(c) more suitable for low temperature work ;
(d) readily available at all times ;
(e) protective atmospheres were more simply obtainable ;
(f) the producer gas furnaces could be more easily converted to town's gas than to oil, and distribution mains were available.

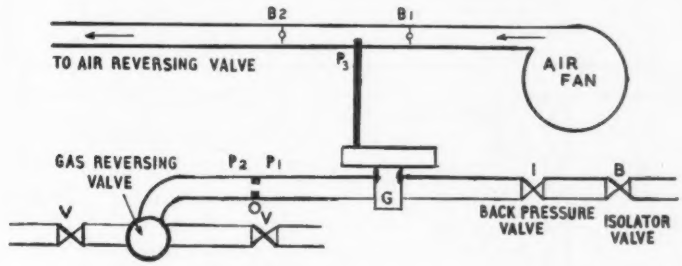
Negotiations were begun with the Gas Board, after which a 12-mile length of high pressure gas main was laid to the works. The gas pressure is reduced from 10 - 20 p.s.i., to 6 in. W.G., by a governor and then fed into a ring main.

3.2.4 *the change-over to town's gas*

The layout of the producer gas main is shown in Fig. 6. It was of ample size for the distribution of town's gas, since it had to pass only about one-third of the previous gas volume and higher pressures were available. The " ring main " made the conversion to town's gas without losing much production a fairly easy matter, while keeping the cost of new mains to a minimum.

AIR-GAS RATIO CONTROL USING A ZERO GOVERNOR

Fig. 7.



A new length of main was erected to join points B and C, and blanking-off plates were inserted at flanges in the main at E and D. Conversion of the furnace and cleaning of the main between E and D was then begun, the remaining furnaces between B and E still being operated on producer gas via the new section B C. On completion of the first furnace, a third blanking plate was inserted at F allowing work to start on the furnace and main between E and F while town's gas was fed through A as far as E to the first converted furnace. When the second furnace was ready, the plate at E was transferred to G, isolating section G F and allowing town's gas up to F. By leap-frogging the blanking plates in this way, all the furnaces between A and B were successively converted with only one or two furnaces out of production at any one time. Using a similar procedure, the rest of the furnaces in the works were converted, and a new heat treatment plant installed with very little inconvenience or loss of production.

3.2.5 *forging furnaces*

There were 50 forging furnaces to be converted to town's gas incorporating the desirable features mentioned in 2.2, at a minimum cost. The basic design of the reversing regenerative furnaces was sound as there was no flame impingment on the stock, combustion space was adequate and the fairly slow mixing of gas and air in the closely spaced uptakes resulted in a sheet of flame spreading up the side wall, across the roof and almost down to the ports on the exhausting side. This large area of soft flame gave good temperature uniformity with producer gas and was expected to do so with town's gas.

The regenerators were quite effective, giving higher air preheat temperatures than could be obtained from metallic recuperators, and so were retained. This meant that no brickwork modifications were necessary except for making good round the burners, and uptakes.

After trials on a town's gas furnace at another works, a simple form of air/gas ratio control using a zero governor was decided upon. A schematic diagram (Fig. 7) illustrates the principle.

The flow of air from the fan at 6 in. W.G. pressure is controlled by the butterfly valve B1 and passes a preset butterfly valve B2, to the air reversing valve. The air pressure at a point P3, between B1 and B2, is loaded on to the top of the diaphragm of a zero governor G. This type of governor has the weight of its moving parts (diaphragm and valve) supported by a spring so that the outlet gas pressure is equal to the air pressure applied to the top of the diaphragm. Downstream of the governor is an orifice plate (with pressure tappings, P1 and P2, for metering the gas flow), the gas reversing valve and a plug cock (V) on each side.

The effect of partially closing B2 is to reduce the air/flow and increase the air pressure at P3, which further loads the governor, increasing the gas outlet pressure and the gas flow and hence reduces the air/gas ratio. Thus, operation of B1 controls both air and gas pressures at P3 and P1, respectively, while B2 controls the air/gas ratio. The flows obtained for maximum air and gas pressures at P3 and P1 are set using valves B2 and V, which are afterwards locked in position.

This system has worked quite well, giving good proportioning of gas and air with single lever control over a turndown range of 6 : 1, which is quite adequate for furnaces of this kind. Other advantages are the low cost, since two butterfly valves and plug cocks are considerably cheaper than a gas/air proportioning valve, particularly when 50 furnaces are involved. Less rearrangement of the pipework was needed, as the gas and air pipes did not need to be brought together as for a proportioning valve.

Automatic pressure control is desirable to prevent air infiltration with its deleterious effect on furnace efficiency and temperature uniformity, but the cost of instruments would not be justified for furnaces of this size.

As a second stage in furnace development, the damper plate on the exhaust fan outlet is to be connected to the control butterfly B1. The connecting linkage will be adjusted so as to maintain a slight positive furnace pressure at hearth level over the turn-down range. Automatic reversal of the regenerators is to be adopted in this second stage of development to ensure maximum preheat temperature.

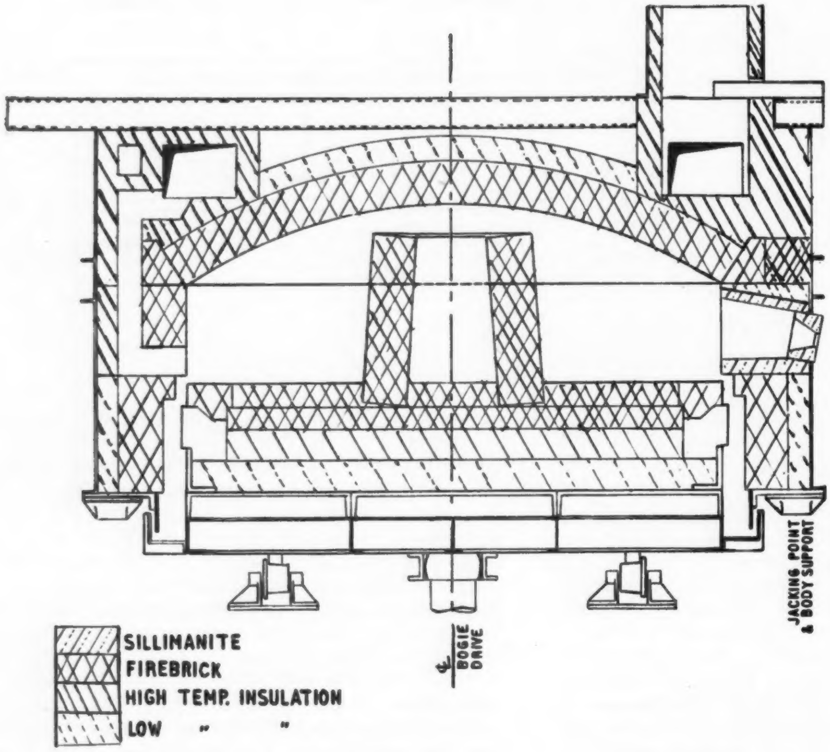


Fig. 8. Rotary Hearth Reheating Furnace.

3.2.6 *the continuous furnace*

For the longer production runs, especially on high speed presses, a continuous furnace is more suitable than a batch type furnace. Although a continuous counterflow pusher type furnace is probably more efficient than a rotary hearth furnace, the latter type was chosen due to site conditions, and because one man can charge and discharge the furnace, since these two doors are adjacent. This results in a saving of labour costs.

A cross-section of the furnace is shown in Fig. 8. The lining is of firebrick with backing insulation, since there is little advantage in using insulation at the hot face in a furnace working for long periods within a narrow range of temperature. The air/gas ratio is controlled by a proportioning valve, but the furnace pressure is manually controlled, as during long production runs the gas consumption is fairly steady, and little manipulation of the damper is required. Automatic temperature control is installed, the thermocouple being suspended through the roof with its tip just above the stock in the soaking zone.

A variable speed drive is fitted so that the hearth rotational speed and hence the heating time can be varied to suit the workpiece cross-section. The output rate (nominally 1 ton/hour max.) is then determined by the rate of charging pieces into the furnace.

This furnace is operated with both doors open sufficiently to allow the continuous charging and discharging of billets. Under these conditions, to achieve a positive furnace pressure, most of the waste gases leave the furnace through the doors and very little is available for waste heat recovery, which is thus of a cheap and simple form.

3.2.7 *heat treatment plant*

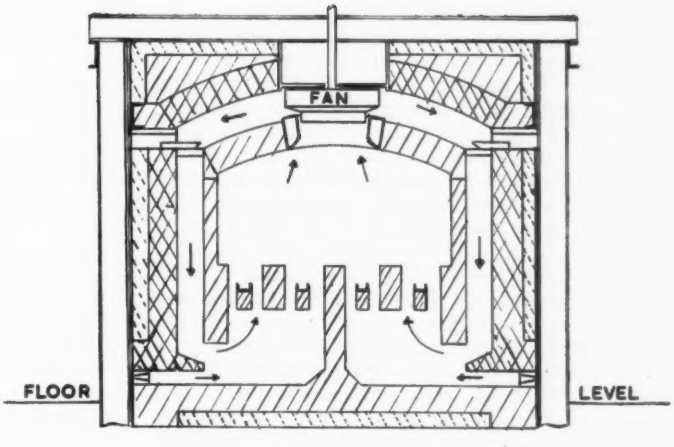
An entirely new heat treatment plant was built to replace the many small furnaces, the intention being to increase the efficiency and flexibility of the plant while reducing the operating costs. The heat treatments carried out are:

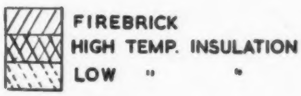
(a) normalising;
(b) oil hardening and tempering;
(c) annealing.

Annealing and tempering involve temperatures up to 750°C and recirculating furnaces were chosen for this range. Normalising and hardening require temperatures of up to 1160°C, for which direct firing is indicated.

A very flexible plant was installed, consisting of two tempering furnaces with forced recirculation, and three dual-purpose furnaces using recirculation up to 750°C or direct-firing without recirculation between 750°C and 1160°C.

Fig. 9.





TEMPERING FURNACE WITH RECIRCULATED ATMOSPHERE

A cross-section of the tempering furnace is shown in Fig. 9. The dimensions are 11 ft. × 6 ft. 6 in. × 3 ft. 3 in. high, with a maximum loading of 5 tons. Nozzle mixing burners fire into chambers under the hearth, where the products of combustion meet the recirculated atmosphere on its way up through the load to the intakes of two centrifugal fans in the crown, which force the gases down ducts in the side walls, back to the combustion chamber. The furnaces are temperature-controlled in two zones, using two gas/air proportioning valves. High temperature insulation is used except for the hearth (which has to withstand the weight of the load and some abrasion) and the inner crown which, being thin, requires a stronger dense brick for stability. At these temperatures, waste heat recovery is a doubtful economic proposition, but automatic furnace pressure control is necessary for efficiency and temperature uniformity.

Cross-sections of the dual-purpose furnaces are shown in Fig. 10. For low temperature work with recirculation, the lower burners only are used. These are of a long flame type firing into combustion chambers under the hearth. Damper C is open and damper B is closed while damper A is for furnace pressure control, the products venting through the pipe D. The furnace atmosphere is forced down the two outer uptakes in the back wall, past the lower burners and into the furnace chamber, from which, after passing through the charge, it is drawn through the ports in the serrated hearth and up the three centre uptakes to the recirculation fan.

For high temperature work, without recirculation, both top and bottom burners are used, and the recirculation fan is isolated by closing tiles in the two outer uptakes in the back wall, closing damper C and opening damper B.

The top burners are nozzle mixing and fire well above the load to avoid flame impingement and localised overheating. The products, after passing through the load, exhaust through ports in the serrated hearth. The lower burners help considerably in achieving a good vertical temperature uniformity.

The top and bottom burners are controlled by two gas/air proportioning valves so that good air/gas ratios can be obtained on both firing systems. With the exception of the hearths, the furnaces are built almost entirely of high temperature insulation. A small degree of preheat is imparted to the air by the simple concentric tube recuperator shown in Fig. 10. Automatic pressure control is fitted.

A charging machine, used in conjunction with an oil quenching machine, air cooling tables and charging tables, was chosen in preference to bogie hearth furnaces mainly on account of reduced labour costs and quicker handling between furnace and quenching. Incoming material is received in stillages and loaded on to trays or bearer bars on the loading tables from which the charger transfers the load to the furnace. In this way two or three men can build up a furnace load in cool conditions while other loads are being heat treated. Bogie furnaces would require more men to discharge and charge the hot bogie and the furnace would be held up while this was being done. With the charging machine, a load can be in the quenching tank within 20 seconds of the furnace door opening, and the furnace can be recharged within two minutes.

Since the inception of this plant the number of forgings requiring retreatment has fallen considerably and, as a result, the amount of inspection required has decreased. For example, after annealing, only 10% inspection for Brinell hardness need be carried out. Previously, 100% inspection was practised. A reduction in the manpower required, from 26 to 12, has been achieved and gas costs have been considerably reduced. For these reasons the capital cost of this plant is expected to be recovered in about five years.

3.3 *practice and control*

The necessity for accurate control of heating for both metallurgical and economic reasons has been mentioned. The problem is that of choosing which of the variables (such as temperature, air/gas ratio, furnace pressure, etc.) to control and the type of equipment and instruments to use. This choice must have regard to furnace size and fuel consumption, the accuracy of control required, the value of the material being treated, and the cost of the control equipment.

For small batch-type forging furnaces, the governor system for air/gas ratio control described has the merits of cheapness and effectiveness. Larger furnaces using more gas would justify the use of gas/air proportioning valves or the metering of both gas and air with the gas flow controlled from the position of the pointer on the air flow meter (or *vice versa*). The furnace pressure should be controlled within reasonable limits. With insufficient or negative pressures, air infiltration will give poor temperature uniformity and an increased fuel consumption. Excessively high pressures result in flame " sting " at doors and openings with increased wear and tear at these places, leaving a smaller volume of products available for waste heat recovery.

Larger furnaces would justify automatic control by instruments, but a simple linkage between damper and operating valve is sufficient for use on small furnaces. The characteristics of the linkage can be varied to match those of the control valve and damper within reasonable limits, but individual setting will be needed.

The main problem with automatic temperature control of forging furnaces is the situation of the control thermocouple. It must be placed so that it will give a temperature reading as near that of the billets as possible, otherwise arbitrary control temperatures have to be set which may vary from furnace to furnace and even with billet size. In addition, the couple must be in a position where it is not easily damaged.

The thermocouple reading may be used to aid the manual control of a furnace when the value of the charge is not high and conditions are not critical, but for high alloy stampings, such as gas turbine discs, automatic temperature control is advisable. A high-low type of instrument controlling a small pulling

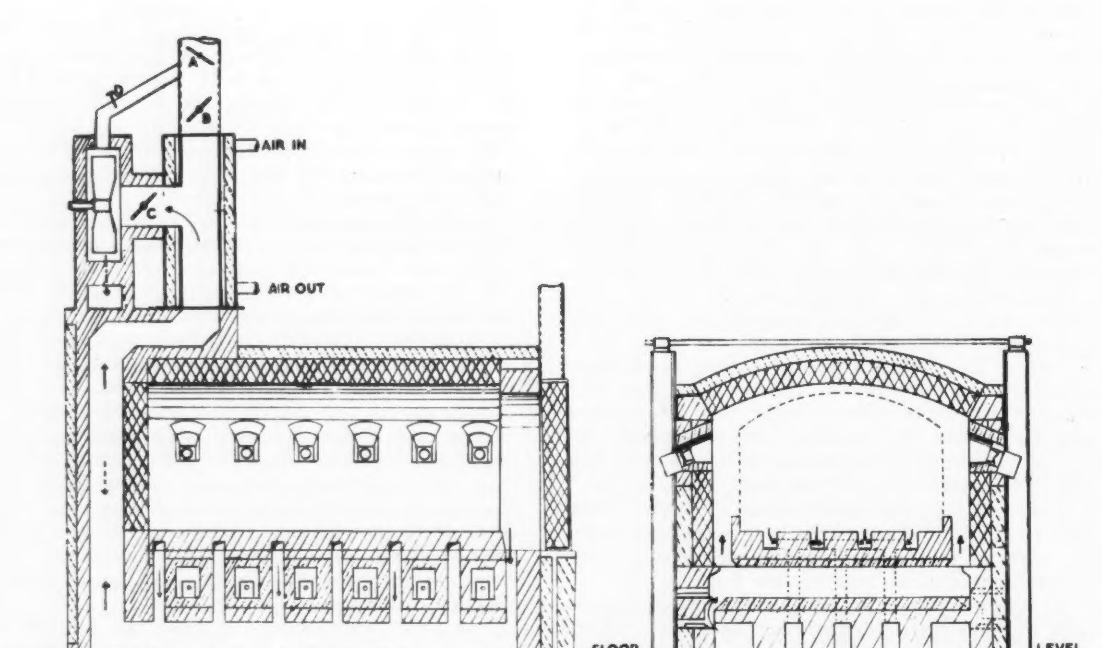


Fig. 10. Town's gas fired heat treatment furnace with direct firing or recirculation.

motor to operate the control valve has been installed, and works very well. This type of control gives a constant "hunting", but the amplitude and frequency of the oscillation can be reduced by setting the minimum gas flow at a rate just too low to maintain the lowest temperature required.

As previously mentioned, the heat treatment furnaces can take charges up to 5 tons in weight and some treatment cycles are very critical. The instruments and control gear are, therefore, fairly elaborate, particularly on the dual purpose furnaces.

All the heat treatment furnaces have air/gas ratios controlled by proportioning valves, and furnace pressures are automatically controlled by pneumatic power cylinders fitted with position control units to actuate the "butterfly" dampers.

The tempering furnaces have automatic temperature control in two zones, using two-term electro-pneumatic instruments, the power cylinders operating the two proportioning valves. The dual purpose furnaces are similarly controlled, but as a single zone. A six-point temperature recorder and gas flow meter are installed on each furnace.

All heat treatment furnaces are fully protected against power failure, loss of air or gas pressure, failure of cooling water or excessive temperature of the recirculating fan. Any one of these events closes the solenoid valve in the gas line and sounds an alarm in the instrument house where all the instruments are grouped.

The rotary furnace has automatic temperature control, the thermocouple being suspended through the roof in the soaking zone, with the tip of the couple a few inches above the largest piece likely to be charged into the furnace. Although the couple indicates a temperature between that of the billets and the furnace gases, during continuous working its temperature is very close to the billet temperature.

All the temperature controllers will reduce the gas flow to the minimum if a fault develops in the thermocouple circuit.

4. possible future furnace design and control

Other methods of heating and control have been developed in recent years which offer advantages under certain conditions.

Induction heating is now well-known, and for long production runs would be used, in spite of the high relative cost of electricity, due to the high speed of heating with very little scale formation. With this method of heating, handling can be very largely mechanised with a consequent saving in labour costs, and there are no standby losses or time delays waiting for billets heating up.

As an alternative to induction heating for long production runs, a continuous counterflow furnace can be considered. With separately fired soaking and heating zones and an unfired preheating zone, full control of heating rates is obtained, combined with very low fuel consumption. Variations in billet sizes are more easily dealt with than with induction heating, and with automatic temperature control on both fired zones, delays due to die changes, meal breaks, etc., can be accommodated, but with more scaling owing to the longer time spent in the furnace. On this count, induction heating has the advantage.

Experiments have been carried out both at B.I.S.R.A. and in the U.S.A. on the high speed heating of billets; in the case of B.I.S.R.A. this was done with high speed steel ingots up to 4 in. square with no trouble due to internal cracking. Rapid heating is achieved by placing the billets in a furnace maintained several hundred degrees above the required forging temperature, and withdrawing them when the billet surface reaches forging temperature. It is stated that adequate temperature uniformity between surface and centre is achieved while the billet is being transferred from the furnace to the press or hammer. Faster heating is thus obtained due to the higher temperature differential between furnace and charge, and hence scaling is reduced. However, close control of the time the billets spend in the furnace is essential as if it is too long, overheating will result. Furthermore, any delay at the press or hammer means that the furnace has to be emptied quickly. This technique will require much more research before any decisions may be taken as to its suitability for the range of alloy steels used.

In recent years, several methods of scale-free heating for forging have been developed. To produce a non-scaling atmosphere at 1200°C from town's gas requires additional heat from another source, as a flame temperature of 1200°C cannot be obtained. The use of large muffle furnaces is impracticable due to the difficulties of maintaining a large muffle in a gas-tight condition, and of conducting sufficient heat through the muffle wall without excessively high temperatures on its outer surfaces. Radiant tubes would be expensive in first cost and maintenance for a furnace of any size. Two methods of overcoming these difficulties have been patented, one using oxygen for combustion and the other, high values of preheat.

An example of the first method is shown in Fig. 11 and burns town's gas with a deficiency of preheated oxygen to produce the necessary atmosphere. In the absence of atmospheric nitrogen the flame temperature is higher and forging temperatures can be obtained. The excess town gas is then burnt in a second larger preheating chamber, secondary air being introduced at the point of entry into the chamber. On leaving the preheating chamber the completely burnt mixture passes through recuperators to preheat the primary oxygen and secondary air.

The second system is shown in Fig. 12. Town gas is burnt with a deficiency of air to produce the non-scaling atmosphere. A larger proportion of the heat required to raise the flame temperature sufficiently high is supplied by the air which is preheated to 1000°C. This is achieved by regenerators with a heat-resisting metallic filling, the excess gas being burnt at the entry to the exhausting regenerator with secondary air introduced at this point. Some completely burnt waste gases are recirculated from the outlet to the inlet of the exhausting regenerator to increase the mass flow and the heat transfer coefficient within the regenerator. Reversal times are 2 minutes.

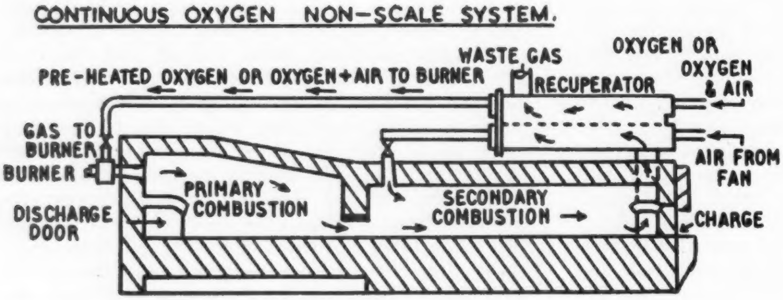


Fig. 11.

With both systems, the initial heating up is accomplished with complete combustion in the furnace chamber, and the change to reducing atmosphere is made when the required furnace temperature is approached.

The advantages of scale-free heating are: elimination of the metal loss (which is important with expensive steels, such as high speed steel), better surface finish and reduced die wear. However, scaling begins as soon as the billet is withdrawn from the furnace, unless it is protected in a suitable inert atmosphere (e.g., nitrogen). A third method has been practised in America and Germany involving the injection of lithium carbonate into the furnace atmosphere, preferably by injecting through a burner. The lithium carbonate is claimed to vaporise on passing through the flame and to condense on the billet, forming a thin black skin which protects the billet from the furnace atmosphere (10% deficiency of air), and from the air when withdrawn from the furnace. The skin is also claimed to act as a lubricant and prolong die life by up to 400%. Small scale tests of this method are being arranged.

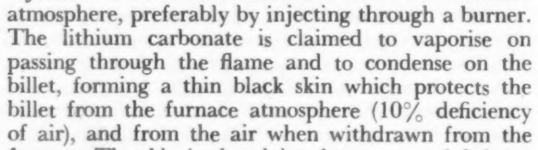


Fig. 12. Non-scaling system with high air preheat.

The use of high temperature insulating refractories has been increasing and is now normal practice in heat treatment furnaces. For forging furnaces, however, careful selection of the type of brick is necessary and tests have been carried out to compare the different bricks, and evaluate the fuel saving and the life of the furnace lining under the arduous conditions of a drop stamp shop or forge department. These tests are necessarily long-term and are not yet complete, but certain conclusions can be drawn:

1. The chief cause of failure is spalling about 1 in. to 1½ in. behind the high temperature face, coupled with shrinkage of the brick which allows the spalled piece to fall out. The depression left exposes more of the neighbouring bricks and the action is progressive, until the lining becomes too thin and has to be replaced. The shrinkage observed over a long period is much greater than that shown in the standard two-hour test and a longer shrinkage test seems to be required.

2. The fuel saving obtained depends largely on the use to which a furnace is put. As an example, a furnace worked for one eight-hour shift and closed down overnight reaches 1200°C in half the time required for a firebrick-lined furnace, and uses half the quantity of gas. Having reached equilibrium conditions later in the day the gas consumption to maintain 1200°C is also lower than for a firebrick-lined furnace. The extent of this difference, however, depends upon the wall thickness and the presence or absence of low temperature backing insulation.

3. Even though a much shorter life is expected than from a firebrick lining, the saving in fuel and heating up times will amply repay the extra cost of the insulating brick, and the more frequent relinings required. More furnaces are being relined with high temperature insulation as they become due for rebuilding, so that experience with the different types of brick should accumulate more rapidly.

(*concluded on page* 384)

A Comparison between Work Factor and Methods Time Measurement Systems in Work Measurement for Short Cycles

by B. KRISHNA, B.Sc.(Eng.) and S. EILON, Ph.D., M.I.Prod.E.

THE introduction of predetermined time systems (M.T.M., W-F., M.T.A., B.M.T., etc.) over the past three decades aroused great interest among practitioners in the field of work measurement. The development of these systems was a natural sequel to micro-motion analysis and the use of basic motion elements as suggested by Gilbreth and Taylor. Work measurement by stop-watch requires rating of the performance of the observed operator, and this implies an element of judgment on the part of the observer, a feature that naturally leaves the field wide open to discussion and disagreement as to the final time standards set by time and motion study engineers. If any sequence of motions, so it is argued by authors of the predetermined time systems, can be described as a combination of independent basic motions, then it should be possible to set time standards for these motions, through which the cycle time of the whole operation can be easily derived. This approach has an obvious appeal in that it does not require time measurement on the shop floor, and the main analysis can be carried out in the office; also there is no need for any human judgment in specifying the rating of the operator.

Attractive as this philosophy may seem, the systems have gradually given rise to some controversy regarding the validity of the basic time values. The opponents of the systems argue that some of the assumptions on which these techniques are based are fundamentally wrong and therefore cannot be expected to produce satisfactory results. The proponents of the systems claim, however, that the systems work and many examples of successful applications in industry have been cited. In the absence of conclusive evidence on the part of the authors of some of these systems, it has been extremely difficult to ascertain the validity and significance of the data on which the predetermined times are based, and this factor has naturally only added to the controversy in this subject.

previous research

It is assumed in all these systems that the elemental motions are independent of each other and are therefore cumulative in nature and this fundamental concept has been the subject of many research projects. Researches by Barnes and Mundel [1], Abruzzi [2], Nadler and Denholm [3], Wehrkamp and Smith [4], and Thwaite [5] seem to indicate that there is a certain amount of inter-dependence between elemental motions. One example [5] is shown in Fig. 1, in which the time of one particular basic motion is shown to be dependent on the weight used in the previous motion.

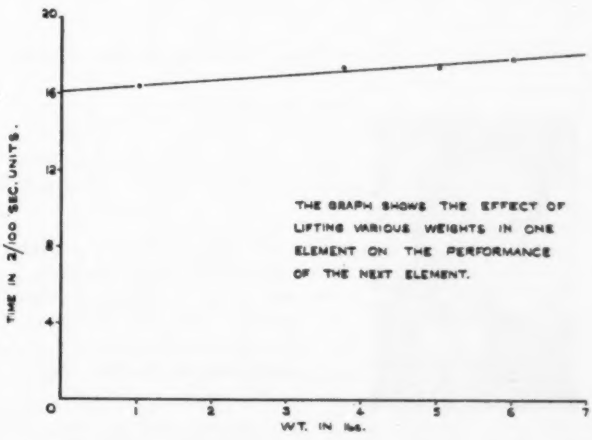


Fig. 1. Effect of weight on the time of the next elemental motion (according to Thwaite[5]).

McGuire[6] investigated (1952) under Davidson's direction the basic elements of M.T.M. and W-F and Holmes systems to study differences in their time values. Analysis of variance was used to test the hypothesis that the difference in times among basic elements and among distances was not statistically significant, when compared with the difference of times among the systems. They found that the determination of what system of data is to be used might have as much effect as the definitions and identifications of motions and distances. This means that the differences between the systems are so large that if one set of data is accurate, others cannot be, since it was found that the difference could not have occurred by chance. Furthermore, significant differential adjustments in time according to length of motion suggested that the differences between the systems could not be accounted for by assuming a difference in the concept of a normal pace. It should perhaps be noted here that McGuire and Davidson selected comparable elements in these systems, using basic or simple case-times only, the idea being to try and avoid controversy resulting from interpretation of data.

In 1953, a survey was conducted by the Factory Management and Maintenance Journal[7] about the practice of predetermined time standards which concluded that "predetermined time values are accurate enough for practical shop application" and added the somewhat cryptic remark that "they have proved as accurate as can be expected when human judgment is involved," but no comments were made about the question of absolute accuracy of predetermined time standards.

Pigage and Reis[8] used a different approach (1954) to confirm the results of McGuire's investigations. They considered three commercial data tables to test the hypothesis put forward by Lang[9], who had suggested that various predetermined time standards could be reconciled by determining a time-distance-control surface for any motion. The idea was to investigate whether a common surface can be obtained, so that differences in time values of the system could be attributed to differences in the level performance expected by the system. The three dimensional surfaces were then plotted for REACH, MOVE and FOREARM-SWIVEL MOTIONS. The results indicated that three different distinct surfaces were obtained instead of one common surface and that differences in time values were found in some cases to be as high as 100%. It was, therefore, concluded that there were serious errors in the derivation of the published data if they were supposed to come from one basic time-distance-control surface.

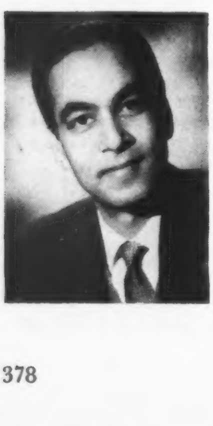
Most of such studies have been confined to elemental motions only and they all indicate differences in time values of different systems, but little attempt has been made to reconcile such differences or to investigate their effect on complete work cycles. The purpose of this work is first to compare the times for some basic elemental motions according to the Work-Factor and the Methods Time Measurement systems and secondly to compare the times of several work cycles.

some aspects of W-F and M.T.M. systems that are difficult to compare

The W-F has been developed from the concept of Basic Motions, which are defined as movements involving a body member, a certain weight, and a distance. The W-F Basic Motion relates to the minimum amount of expenditure of human energy, which presents no "motion difficulty", and when motion difficulty exists, it is expressed in terms of work-factors, which are associated with longer time values to take count of motion difficulties. These work-factors are cumulative and "to avoid multiplicity of tables, all the work-factors relating to movement of a specific body member are arranged to be of equal value by carefully defining the rules that govern their application."

M.T.M., on the other hand, analyses any manual operation into several basic motions according to the purpose of the motion and the conditions under which it is made, each of the M.T.M. basic elements being studied individually with respect to the specific variables of any motion difficulty.

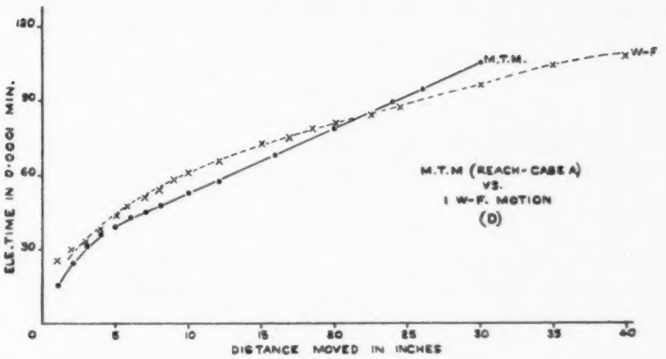
Thus, the systems fundamentally differ in their method of classification of the basic elements and in the way motion difficulties are taken into account.



Dr. Eilon (right) is Reader in Production Engineering at The Imperial College of Science and Technology.

Mr. Krishna (left) is a Graduate in Mechanical Engineering from Banares Hindu University and served his apprenticeship in India at L.R. Engineering Works Ltd., Bombay and Hindustan Machine Tools Ltd., Bangalore, with whom he is presently employed. He attended the postgraduate course in Production Engineering at Imperial College during 1958 - 59.

Fig. 2(a). Comparison of elemental motions.



This is one of the main reasons for the existence of several predetermined time standards. In the case of W-F, it is very difficult to comprehend from the published literature how motion difficulty has been isolated and analysed in terms of work-factors and how different motion difficulties have come to be expressed by the same work-factor, involving the same additional time allowance. In this connection Gomberg [10] commented, " too little is known about the origins of the data of most microscopic standard data plans ", and he even went on to say that " on the basis of inconsistency among themselves, we can conclude that they are very dangerous to use."

comparison of elemental motions

The published data enable us to find the relationship between time and distance for certain comparable elements in both the systems. Accordingly, the M.T.M. elements of REACH and MOVE have been converted into equivalent W-F motions, and the following graphs have been plotted to determine the consistency of their time values :

Fig. 2(a) shows the characteristics plotted from actual data of the M.T.M. element, REACH — Case A, " Reach to object in fixed location." According to W-F, this is to be classed as one W-F motion, as it involves a single W-F of " definite stop ".

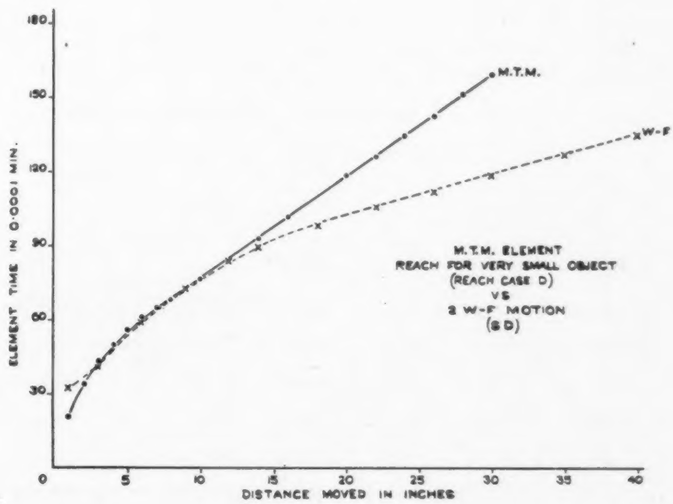
Fig. 2(b) describes the time for M.T.M. element REACH — Case D, " Reach to a very small object or where accurate grasp is required ", which in W-F terms involves two work-factors; one of " definite stop " and one of "steering" or "directional control."

Fig. 2(c) is a comparison between the M.T.M. element MOVE — Case B (hand in motion) and the W-F Basic motion (i.e., no motion difficulty).

Fig. 2(d) shows curves for M.T.M. element, MOVE — Case B, " Move object to indefinite location (with a weight of 12.5 lb), and a three W-F motion (one of " definite stop " and two for " weight ").

Fig. 2(e) shows curves for M.T.M. element, MOVE — Case C, " Move object to exact location," and two W-F motion (one for " definite stop " and one for " directional control ").

Fig. 2(b). Comparison of elemental motions.



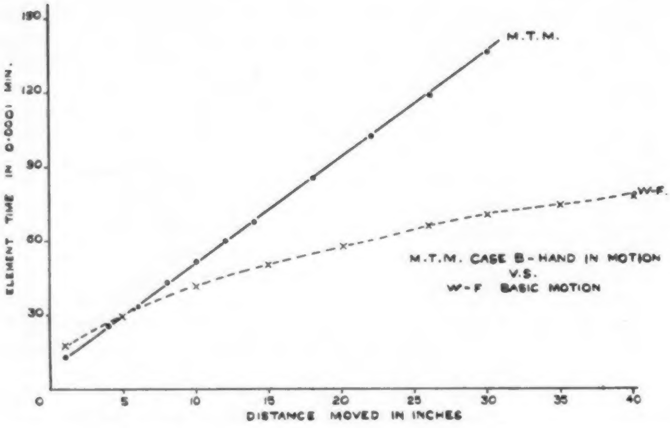


Fig. 2(c). Comparison of elemental motions.

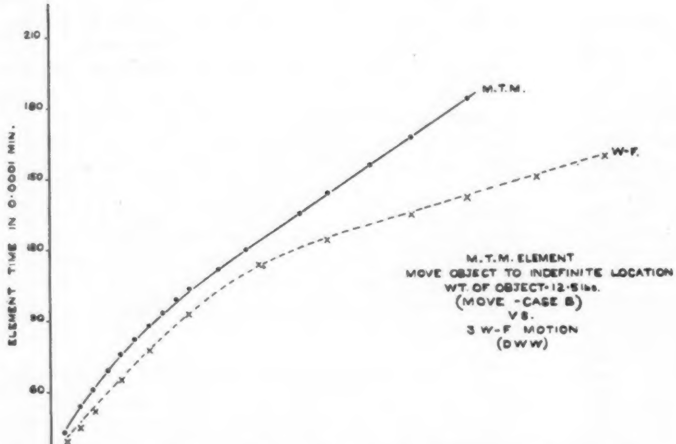


Fig. 2(d) Comparison of elemental motions.

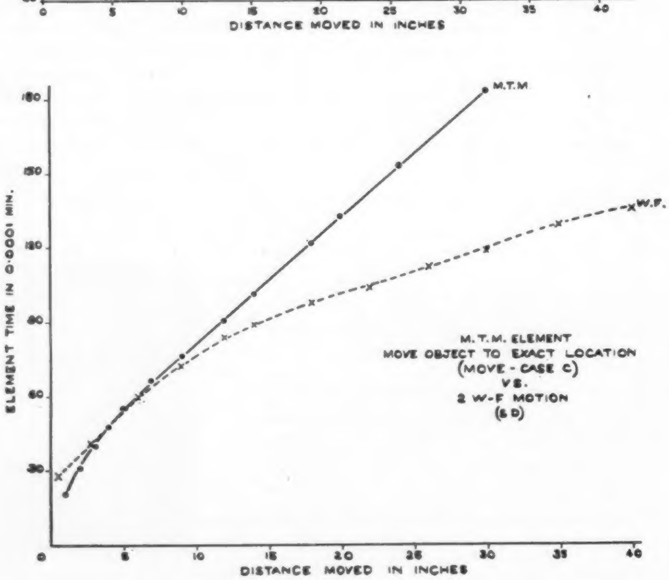


Fig. 2(e) Comparison of elemental motions.

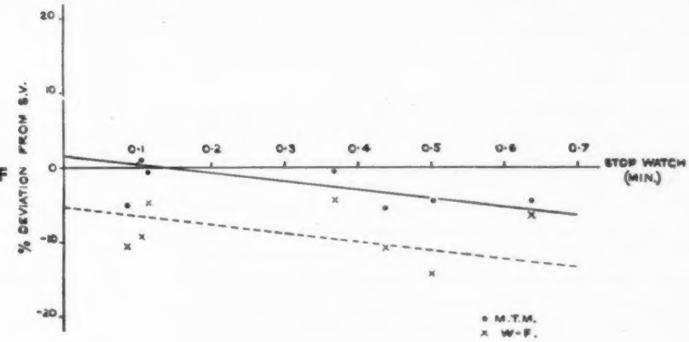


Fig. 3. Comparison between M.T.M. and W-F for seven work cycles.

comparison of some short work cycles

Several short work cycles of a repetitive nature have been selected for the purpose of comparison of W-F and M.T.M. and these are summarised in the Table below and in Fig. 3. The stop-watch time values cited by the authors have not been rated or levelled, so that while these stop-watch time values do not pertain to indicate performance of a normal operator, they do suggest an average figure, as they were based on a comparatively large number of observations.

discussion of results

First, it is interesting to note that in the case of the elemental motions, the values given by W-F are almost always tighter than those suggested by M.T.M. The comparison in Figs. 2(a) - 2(e) shows that the rate of change in M.T.M. time values for a given elemental motion slowly declines as the distance increases, and becomes constant roughly beyond 5 in. so that time values linearly increase with distance beyond this point, while values in the W-F system become linear at a much later stage, somewhere in the region of about 20 in. and in some cases even 40 in. This implies that the discrepancy between the values of the two systems increases quite appreciably with the distance involved in elemental motions, and from the results shown in the figures it would seem that the difference becomes quite significant beyond a distance of some 10 in. - 15 in. and that would account for some of the basic differences between time values for work cycles as derived from the two systems.

One difficulty in comparison lies in the measurement of distance for the elemental motions. In the M.T.M. system the distance is defined as the " traversed distance," whereas in the W-F it is defined as the " plan distance ". According to Nadler and Denholm [3], the more complex the task the less the hand rises above the work surface and *vice versa* and they suggest that " the change in actual distance moved for the same linear distance caused significant time differences ". These results would indicate that the validity of the constant rate of change in time values in the two systems should be re-examined. Furthermore, Barnes [11] (1933) suggested that it requires very little longer for the hand to move through long distances (24 in.) than for the hand to move through short distances, that horizontal patterns of movements show slower travel time than vertical patterns of movements and that downward directions of motions are faster than upward motions [12]. Similarly, simple transport movements are slower when the direction of movements is from the

COMPARATIVE ANALYSIS OF SEVERAL WORK CYCLES

No.		Reference	Measured by Stop-Watch (min.)	Pre-determined Time Values (min.)		% Deviation from Stop-Watch	
				M.T.M.	W-F	M.T.M.	W-F
I	Bolt and washer assembly (old method)	Barnes[14]	0.0840	0.0798	0.0750	−5.0	−10.7
II	Straightening and folding terry towels	Bailey and Presgrave[15]	0.1018	0.1029	0.0924	+1.1	−9.2
III	Bolt and washer assembly (improved method)	Barnes[14]	0.1100	0.1093	0.1046	−0.6	−4.9
IV	Filling a pin board (two boards next to each other)	Barnes[16]	0.3666	0.3640	0.3516	−0.7	−4.1
V	Filling a pin board (two boards separated by 12 ins.)	Barnes[16]	0.4333	0.4087	0.3870	−5.7	−10.7
VI	Filling a pin board (two boards separated by 24 ins.)	Barnes[16]	0.5000	0.4775	0.4266	−4.5	−14.6
VII	Filling a pin board (one handed method)	Barnes[16]	0.6333	0.6027	0.5940	−4.8	−6.2

body and quicker when it is towards the body, and tapping motions are slower when they are in the up and down direction than when the tapping is performed sideways [13].

The comparison of time values for work cycles in Fig. 3 again suggests that the W-F system specifies tighter time values than the M.T.M. system. Bearing in mind that the stop-watch time values referred to have not been rated, the abscissa in Fig. 3 should be regarded as a convenient datum line rather than a yardstick for assessing absolute accuracies of these predetermined time systems. One interesting result indicated by this comparison (at least for a few work-cycles shown in Fig. 3) is that the slope of the two lines is approximately the same,* which would suggest that as far as cumulative times for elemental motions are concerned, the two systems practically differ by a constant time value. Although some previous research on time values of elemental motions seem to dismiss the idea that discrepancies in times in the M.T.M and W-F systems relate to different levels of operator performance, the definition of a normal operator according to the two methods is suggestive: the W-F system specifies time of performance to be expected from "an experienced and skilled operator", whereas the M.T.M. is designed for "the normal or average worker". These definitions seem to imply that the W-F system expects higher output from the operator, as indeed verified in Fig. 3, the results of which are tantamount to an indication that a basic difference in the concept of the normal pace of performance is built-in the systems. The characteristics of the time functions of elemental motions in terms of distance travelled (as in the examples in Figs. 2(a) - 2(e)) would seem to support such a suggestion.

However, the work-cycles taken as a basis for Fig. 3 are all below 0.7 minutes and further work on longer cycles is required to determine whether the slope of the lines does remain the same for longer time values. Furthermore, bearing in mind that most of the motions described in these work-cycles were rather short (only the sixth work-cycle included motions of more than 20 in.), one would perhaps expect that when longer motions are involved, the discrepancy between the two systems would increase, in view of the comparison of the elemental motions shown in Figs. 2(a) - 2(e).

As so much criticism is levelled at the basic assumption in the predetermined time systems that elemental motions are independent of each other (as far as time values are concerned) further research is indicated into the cumulative effect of interdependence of motions within whole work-cycles. It is conceivable, first that some of these effects may cancel each other, and secondly that the overall effect may depend on the cycle-time. After all, in practice we are concerned with complete cycles, and it is often from the study of these that confidence or mistrust in the practicality of any system emanates.

acknowledgments

The authors wish to thank Mr. H. C. Wiltshire, of The College of Aeronautics, Cranfield, for discussing some of the results mentioned in Thwaite's Thesis; also Professor R. M. Barnes, of the University of California, for sending details about the work-cycles published in some of his Papers and for providing drawings of the work-place layouts used in his experiments.

* based on the method of least squares.

REFERENCES

1. BARNES, Ralph M. and MUNDEL, Marvin E. "A Study in Simultaneous Hand Motions." Studies in Engineering, Bulletin 17. University of Iowa, 1939.
2. ABRUZZI, Adam. "Work, Workers and Work Measurement." Columbia University Press. 1956.
3. NADLER, G. and DENHOLM, D. H. "Therblig Relationships: I. Added Cycle Work and Context Therblig Effects." Journal of Industrial Engineering. Vol. 6, No. 2, March - April 1955, pages 3 - 4.
4. WEHRKAMP, R. F. and SMITH, K. U., "Dimensional Analysis of Motion: II. Travel Distance Effects." Journal of Applied Psychology. Vol. 36, 1952, pages 201 - 206.
5. THWAITE, J. Thesis (unpublished). "An investigation of the Interaction Effects of Elemental Motions." The College of Aeronautics, Cranfield, June 1956.
6. DAVIDSON, H.O. "Functions and Bases of Time Standards." American Institute of Industrial Engineers, 1952.
7. "P.T.S.: A Survey of Current Practice." Factory Management and Maintenance. Vol. 3, No. 9, September, 1953, pages 134 - 139.
8. PIGAGE, L.C. and REIS, I. L., "Incompatibility of Predetermined Time Systems." A.S.M.E., Paper No. 54-F5, 1954.
9. LANG, A. M. "Methods — Time Management." Proc. of the Eighth Annual Time Study and Methods Conference, S.A.M. and A.S.M.E., New York, 1953. pages 101 - 102.
10. GOMBERG, W. "A Trade Union Analysis of Time Study." Science Research Associates. 1958. page 163.
11. BARNES, Ralph M., Ph.D. Thesis: "Practical and Theoretical Aspects of Micromotion Study." Cornell University 1933.
12. DAVIS, R. T., WEHRKAMP, F. R. and SMITH, K. U. "Dimensional Analysis of Motion: I. Effects of Laterality and Movement Direction." Journal of Applied Psychology, Vol. 35, 1951, pages 363 - 366.
13. CHAPANIS, A., GARNER, W. R., and MORGAN, C. T. "Applied Experimental Psychology." Wiley 1949. pages 282 and 284.
14. BARNES, R. M. "Motion and Time Study." Wiley 1958, page 220.
15. BAILEY, G. B. and PRESGRAVE, R. "Basic Motions Time Study." McGraw Hill, 1958, page 137.
16. BARNES, R. M., "Work Methods Manual." Wiley, 1955, pages 20 and 65.

INTERNATIONAL STANDARDISATION AND THE FREE TRADE AREA

by Dr. H. M. GLASS

Deputy Technical Director,
British Standards Institution.

THE relationship on standardisation between the U.K. and the countries of the potential Free Trade Area cannot be assessed without a fair consideration of the wider relationships of this country with larger organisations concerned with international standardisation.

1. European standardisation before EFTA

(a) pre-war

Before World War II, European countries were associated with the work of two main international standardisation bodies, the International Standards Association (ISA) and the International Electrotechnical Commission (IEC). The former covered the general field of standardisation and the latter, as the name implies, the electrical side. In general, Continental European countries played the most prominent part in ISA activities. The U.K. took part but its influence was not especially strong.

International standardisation in Europe ceased during the World War II and ISA never functioned again. The IEC continues to thrive however.

(b) post-war

After 1945, general standardisation activities between countries were set going again with the formation of the International Organisation for Standardisation (ISO). This organisation was of world-wide appeal. In Europe other special agencies, of a governmental character, began to interest themselves in standardisation, although this was not their primary objective. Such agencies include the O.E.E.C., the Coal and Steel Community of the High Authority and the E.C.E. These agencies have association with ISO at certain points, for example, in relation to steel, coal and agricultural products.

(c) the ISO

Unquestionably the most important world organisation dealing with general standardisation is the ISO. Its member bodies are the national standards organisations (in the case of U.K., the B.S.I.) of over 40 countries spread over all five continents. More than 90 technical committees now operate under ISO.

(d) the IEC

This is the most important world organisation concerned with electrical standardisation. At present there are more than 30 member bodies and over 80 technical committees and sub-committees.

2. relationship of EFTA with the ISO and IEC

An analysis of the parts played by the Common Six and Outer Seven countries in ISO and IEC is of considerable interest. European countries shoulder the major responsibilities in running the technical work of these organisations.

The U.K., besides being a member of nearly all committees of ISO, holds the secretariat of more than 20. The Outer Seven are, in all, responsible for the secretariats of 37 ISO committees. The Common Six have the secretariats of 39, with France in the leading position of having 16. Thus, about 80% of the ISO committtees have the national standards body of an EFTA country as the secretariat.

The position in IEC is very similar. Common Six secretariats amount to 38 and Outer Seven secretariats to 31, so that EFTA countries hold the secretariats of more than 80% of the committees in this organisation too.

With European countries playing such a great part in ISO and IEC work, the need for them to set going a further effort in the field of international standardisation will be questioned. The world-wide interests of ISO and IEC must, however, be recognised. It does not follow that the emphasis or pace of these large organisations is that required by EFTA. It is also true that other regional standardisation activities have gone on quite successfully alongside the broader efforts of the two world-wide organisations. Thus, in the case of the United Kingdom, a strong lead in

ISO and IEC work has not been undermined by participation in America-Britain-Canada developments in standardisation, or in the work of the Commonwealth Standards Conferences.

3. EFTA standardisation policy

In the past year or so there has been some progress in the development of a European standards movement through the potential members of a European Free Trade Area. But, from the start, united development has been hampered by the division into two communities, the Common Six and the Outer Seven. The Common Six have worked out a method of procedure and an immediate programme, and have allocated to the member countries of the Six the organisational responsibility for the subjects of first priority. These include :-

1. Definitions used in building
2. Hoisting equipment
3. Asbestos cement products
4. Plastics tubes and products for building
5. Prefabricated partitions
6. Functional dimensions of furniture and kitchen appliances
7. Manufacturing dimensions of sanitary appliances
8. Banking

The marked emphasis on work in the building field will be noted.

Although these arrangements have been made in association with some of the members of the Outer Seven, the position in this work of countries other than the Common Six is mainly that of being observers who are provided with information on what the organising countries are doing and are able to comment on the proposals made, but who are in no real position to set the policy or to modify any final decision taken by the Six.

In the period of almost two years that has elapsed since the first moves were begun, comparatively little information on the development of the selected projects has been forthcoming. Proposals have been received on functional dimensions of sanitary appliances and on architects' drawings, and these are under consideration by the appropriate B.S.I. committees.

The unity now achieved in the foundation of the Outer Seven provides an opportunity for the proposal to be made from a position of strength that the 13 countries of the Six and Seven could with mutual benefit combine in a truly European standardisation programme. Such a programme would take due account of the ISO and IEC work. It would not attempt to initiate regional activity on projects which were already being competently handled by these larger international bodies. From the standpoint of matters of major interest to Western Europe as a whole, it would, however, urge forward work which was either not being dealt with in ISO or IEC, or on which the rate of development, though satisfactory in the broadest sense, was not considered adequate for European purposes.

EVOLUTION OF STOCK AND HEAT TREATMENT FURNACES FOR DROP FORGINGS — concluded from page 376

5. conclusion

The main points of furnace development have been those of fuel economy and control. Contributing to the former are close control of fuel/air ratio and furnace pressure with waste heat recovery, and the choice of suitable refractories. The latter results from the development of thermocouple materials and instruments for measurement and control. The actual design of a furnace is governed by the stock to be treated and no mention has been possible of the furnaces designed for specific purposes. Although much is known of furnace technology, a lot of design work is still a matter of experience, and a great deal has yet to be discovered.

acknowledgments

The author expresses his appreciation to the Directors of The Firth-Derihon Stampings Limited for permission to publish this Thesis, and to all members of the Technical Staff of The Firth-Derihon Stampings Limited, and The Brown Firth Research Laboratories for their assistance in providing drawings and technical data.

READING SECTION ANNUAL DINNER

The Reading Section held their Annual Dinner on 1st April, 1960, at The George Hotel, King Street, Reading. About 70 members and their guests sat down to an excellent meal which was preceded by the "piping in" of the Chief Guest, Mr. J. R. Sharp, Joint Governing Director of Lansing-Bagnall Ltd. One of the two Scottish pipers later acted as Toastmaster.

Mr. Sharp, in proposing the Toast, "The Chairman coupled with the Institution", mentioned his long association with materials handling and recently with the founding of the Institute of Materials Handling. The Section Chairman, Mr. H. P. Mott, in reply, drew attention to the fact that Mr. Sharp was his "skipper", and mentioned the rapid and striking growth of their company.

Mr. A. H. Ralph, Deputy Chairman, proposed the Toast "Our Guests", and remarked on the good number of well-known local figures present, representing a large section of local industry. The response to this Toast was made by Mr. W. Green, Director of Nelco Ltd., who gave an extremely witty and entertaining speech based on his experiences and associations with both the Chief Guest and also the Section Chairman in their business.

Music during the Dinner was followed by an entertainment given by Kenway and Young.

HALIFAX AND HUDDERSFIELD SECTION DINNER AND DANCE

The Section's annual social event was held on 26th February last in Halifax, when members were pleased to welcome Mr. G. Ronald Pryor, President of the Institution, and Mr. J. C. Snow who proposed the Toast, "The Institution of Production Engineers". Over 80 members and their guests enjoyed a very pleasant evening. In the photograph are (left to right) Mr. Pryor; Mr. Richard Asquith, Section Chairman; Mrs. Richard Asquith; Mr. Snow; and Mrs. Snow.

SOUTHAMPTON SECTION DINNER - DANCE

This photograph, taken during the evening, includes (from left): Mrs. J. W. Taylor; Mrs. J. B. Turner; Mrs. J. C. Dacombe; Mr. J. B. Turner, Section Chairman and Works Manager, Hawker Siddeley (Hamble) Ltd.; Mr. J. C. Dacombe; Mr. W. S. Elliott, I.B.M. Laboratories; The Worshipful the Mayor of Southampton; Mr. E. L. Freeman; Mr. H. W. Bowen, O.B.E., Chairman of Council; Mrs. S. Caselton; Mrs. H. W. Bowen; Mr. S. Caselton, Deputy Secretary of the Institution; The Mayoress of Southampton; Mrs. D. Bennion Browne; Mr. D. Bennion Browne, Director, AC-Delco, Southampton; and Mrs. W. S. Elliott.

This annual function is always a most popular event in Southampton, and this year, on Friday, 1st April, nearly 250 members and guests enjoyed a most entertaining evening at the Polygon Hotel.

Mr. J. B. Turner, Section Chairman, presided, and the guests included The Worshipful the Mayor of Southampton, Alderman Mrs. R. M. Stonehouse, J.P.; Mr. H. W. Bowen, O.B.E., (Chairman of Council) and Mrs. Bowen; Mr. J. C. Dacombe (Director and General Manager, Hawker Siddeley (Hamble) Ltd.) and Mrs. Dacombe; Mr. F. L. Freeman (Chief Education Officer, Southampton); and Mr. S. Caselton, Deputy Secretary of the Institution, with Mrs. Caselton.

WESTERN GRADUATE SECTION VISIT TO S.S. UNITED STATES

The fastest liner afloat, *S.S. United States,* was visited by 40 members of the Western Graduate Section when she docked at Southampton on Sunday, 3rd April last, inward bound from New York to Bremerhaven. A conducted tour was made of the passenger accommodation and services, including the galleys, swimming pools and gymnasium.

The visitors were impressed with the facilities available for passengers, no effort having been spared to ensure their comfort. The "United States" is air-conditioned throughout, with individual heat and humidity controls in each stateroom.

"S.S. United States."

The galleys are magnificent, each tradesman having his own working area, and passing his finished articles into a central cooking bay. The extent of the fire-proofing precautions is remarkable, the only wood in the ship being in the grand piano and the butcher's chopping block!

The ship was alongside for only three hours before continuing her voyage, so members were unable to see the bridge and the machinery spaces. Even so, the visit was of great interest and was enjoyed by all.

J. R. CALDER.

SPECIAL MACHINE TOOL ISSUE

In view of the special interest in machine tools at this time — The 1960 Viscount Nuffield Paper by Sir Stanley Rawson, and the Machine Tool Exhibition at Olympia are two of the main events — the Editorial Committee felt that members of the Institution would appreciate the opportunity of reviewing, in the advertising pages of the Journal, a comprehensive selection of the latest developments in the tools of production.

Much interest, also, will undoubtedly be roused by the article on pages 319 - 320, in which the President of The Machine Tool Trades Association, Mr. E. W. Field, O.B.E., describes the future trends of machine tool design.

NEWS OF MEMBERS

Mr. A. A. Jacobsen, Member, formerly Works Manager of the Witney Sub-Division of the Motor Accessory Division of S. Smith & Sons (England) Ltd., is now Works Manager of Roneo Ltd., Norwich. Mr. Jacobsen serves on the Conference Organising Committee and the Education Committee, and is Chairman of the Practical Training Sub-Committee.

Mr. N. E. Langdale, Member, Education Officer of Imperial Chemical Industries Ltd., Witton Works, has been seconded by I.C.I. to perform the duties of Director of Practical Training and Placement at the College of Engineering and Technology, Delhi, for two years, under the Technical Co-operation Scheme of the Colombo Plan.

Mr. A. D. Lidderdale, Member, formerly a member of the Cables Group Board of Telegraph Construction & Maintenance Co. Ltd., and a Director of Toolpro Ltd., has joined Arusha Industries Ltd. as Personal Assistant to the Chairman.

Mr. Leonard Walker, Member, Director of Noble & Lund Ltd., Felling, Gateshead, has been appointed General Manager. Mr. Walker is a past Chairman of the Newcastle upon Tyne Section of the Institution.

Mr. A. R. Bishop, Associate Member, has taken up the position of Senior Production Engineer with Birmingham Sound Reproducers Ltd.

Mr. G. S. Boothroyd, Associate Member, formerly, Production Director, has now been appointed Managing Director of E. Gordon Whiteley Ltd., Morley, Leeds.

Mr. Peter Boyd, Associate Member, has recently been promoted from Chief Planner (Blades) and Production Liaison Engineer to Chief Planning Engineer, D. Napier & Son Ltd., Acton.

Mr. J. R. Bradshaw, Associate Member, has been appointed Production Controller with I.T.S. Rubber Company, Petersfield, Hants.

Mr. D. J. H. Bridge, Associate Member, formerly Area Sales Manager of Fisher & Ludlow Materials Division, has recently been appointed Sales Director of Finspa Engineering Co., of West Bromwich.

Mr. P. A. Broadbent, Associate Member, has relinquished his position with Birfield-Industries Ltd., and has taken up an appointment as Works Manager of Charles Winn & Co. Ltd., Birmingham.

Mr. F. L. Brodie, Associate Member, has relinquished the appointment of Head of Work Study with the Osram Division of the General Electric Co. Ltd., and has taken up a new position as a Management Consultant with M.W.M. (London) Ltd.

Mr. J. B. Finlay, Associate Member, Manager of Machine Department, Gilbert Lodge & Co. Ltd., was recently elected First Vice-Chairman of the American Society of Tool & Manufacturing Engineers, Sydney Chapter.

Mr. M. H. Hammill, Associate Member, has been appointed to the Board of George Fletcher & Co. Ltd., of Derby.

Mr. W. H. Landmann, Associate Member, has recently taken up an appointment as Performance Engineer at the High Wycombe factory of Charles Colston Ltd.

Mr. H. T. Lossius, Associate Member, has recently been appointed Assistant Chief Engineer of Industrias Quimicas Argentinas "Duperial" S.A., Buenos Aires, Argentina, which is a subsidiary of I.C.I. Ltd.

Mr. G. K. E. McCall, Associate Member, has been appointed Managing Director of Churchill-Redman Ltd., Halifax, Yorkshire. He was formerly Works Director.

Mr. A. H. Mills, Associate Member, has relinquished his position as Tool Division Manager with Messrs. Uddeholm Ltd., Birmingham, and has taken up a new position as Sales Manager to Messrs. Jessop-Saville (Small Tools) Ltd., Sheffield.

Mr. D. B. Richardson, Associate Member, is now an Assistant Lecturer Grade B in Mechanical Engineering at the Brighton Technical College.

Mr. Gordon D. Robson, Associate Member, has been appointed a Director of Noble & Lund Ltd., Felling, Gateshead. Mr. Robson is a past Chairman of the Newcastle upon Tyne Section of the Institution.

Mr. E. Taylor, Associate Member, has recently left England in order to take up a position as Technical Manager of Mather Greaves (Pty) Ltd., in India for a period of three years.

Mr. F. O. Walker, Associate Member, has recently been elected Chairman of the American Society of Tool and Manufacturing Engineers, Sydney Chapter. Mr. Walker is a member of the Sydney Section Committee of the Institution, and is Production Manager for Fairey Aviation Co. Ltd., Australia.

Mr. J. P. de Vall, Graduate, has recently taken up an appointment as Senior Service Representative in the United States of America for D. Napier & Son Ltd.

Mr. E. Hayes, Graduate, has recently resigned his position with Messrs. Richards & Ross Ltd., of Wednesfield, and has taken up an appointment of Development Design Draughtsman with Messrs. Samuel Griffiths Ltd., Willenhall, Staffs.

Mr. H. E. Alan Noble, Graduate, has been appointed a Director of Noble & Lund Ltd., Felling, Gateshead, and takes over the duties of Works Manager. Mr. Noble is a Past Chairman of the Newcastle upon Tyne Graduate Section of the Institution.

Mr. J. M. Williams, Graduate, has been appointed Chief Work Study Engineer, Bristol Aircraft Ltd.

Mr. R. W. Wall, Graduate, has been appointed Assistant Production Controller, Bristol Aircraft Ltd.

Mr. R. J. M. Watt, Graduate, has been appointed Deputy Production Controller, Bristol Siddeley Engines Ltd., Bristol. Mr. Watt is Vice-Chairman of the Western Graduate Section.

THE FUTURE TRENDS OF MACHINE TOOL DESIGN — continued from page 320

extremely hard and brittle materials, is possible by the application of this method. It is an example of the "chipless" machining of material in so far as disintegration of the surface material takes place under the impact of the sound waves directed through a soft tool bit.

This is a field offering vast scope for development. Ultrasonic and spark erosion machine tools are comparative newcomers, but they are firmly established and have an interesting future.

These are trends which can be regarded as inevitable in the immediate and foreseeable future. Beyond this it is a little difficult to see how much further the design and construction of the machine tool can be drastically changed, unless and until the nature of the material and form of the workpiece itself undergoes change with a view to facilitating its production. When this takes place machine tools will be adapted acordingly. This presupposes a great deal of co-operation between user and manufacturer.

DIARY FOR 1960

JUNE 27	**Summer Meeting,** at the Festival Hall, London, preceded by **The 1960 Viscount Nuffield Paper,** at The Royal Institution, London (see Journal Supplement).
AUGUST 24-28	**Symposium,** at The College of Aeronautics, Cranfield. **Subject: "Machine Tool Control Systems"** (see Supplement).
SEPTEMBER 17	**Fourth Graduate and Student Convention,** Birmingham (see Supplement).
SEPTEMBER 21	**The 1960 E. W. Hancock Paper,** in London.
OCTOBER 12-14	**National Conference,** at Brighton. Theme: **"Modern Trends in the Manipulation of Metals"**
NOVEMBER 2	**Annual Dinner,** at the Dorchester Hotel, London.
NOVEMBER 10	**The 1960 Sir Alfred Herbert Paper,** at The Royal Institution, London.

Hazleton Memorial Library

ADDITIONS

Members are reminded of the following **Library** rule, which is frequently ignored:

"The initial loan period is one month, and borrowers may keep books and periodicals for further periods of one month, if they ask the Librarian, and if no other borrower wants them. Applications for renewal may be made by post or telephone."

Aljian, George W. **"Purchasing Handbook: Standard Reference Book on Purchasing Policies, Practices, Procedures, Contracts and Forms."** *New York, London, etc., McGraw-Hill Book Company,* 1958. 28 *sections. Various paging.* £5 16s. 6d.

This handbook deals extensively and in detail with the principles and practice of purchasing. Its usefulness as a practical handbook is mitigated by the fact that the routine of purchasing is to a great extent a matter of local and national procedures and regulations, and much of the detailed description in the book refers to American practices. But insofar as the book deals with principles, and gives generalised descriptions of procedures, it should have value in the United Kingdom for purchasing officers, and engineers whose work is connected with purchasing.

Contents:- The purchasing function — Purchasing department organisation — Policy and procedure manuals — Legal influences in purchasing — Purchase order essentials — Ethical practices in purchasing — How to select sources of supply — Quality: the major assignment — Pricing considerations — Price evaluation — How to analyse value — Forward buying — How inventory control reduces cost — Buying procedures: commodity classes — Considerations in non-repetitive major purchases — Import and export purchasing — Transportation and traffic considerations — Public purchasing — Purchasing in Canada — Disposal of reclamation and salvage materials — Purchasing department budgets — Selection and training of buyers — Performance evaluation of purchasing department — Purchasing department forms and records — Purchasing department library and catalogue file — Glossary of terms — Appendix — Reference tables.

American Welding Society. Welding handbook. 4th edition. Section 2. **"Welding Processes, Gas, Arc and Resistance."** *New York, the Society; London, Cleaver-Hume Press,* 1958. 33 *sections. Various paging. Illustrated. Diagrams.* £3 12s. 0d.

Contents:- Gas welding — Pressure gas welding — Gas welding and brazing equipment — Carbon-electrode arc welding — Shielded metal-arc welding — Bare metal-arc welding — Impregnated tape metal-arc welding — Atomic-hydrogen welding — Inert-gas metal-arc welding — Submerged arc welding — Arc welding equipment — Spot, seam and projection welding — Flash, upset and percussion welding — Resistance welding equipment — Standard welding symbols.

Associated Electrical Industries Limited—*Turbine Generator Division, Manchester and Rugby.* **"The Manufacture of Large Steam Turbines."** *Manchester and Rugby, the Division,* 1959. 31 *pages. Illustrated.*

Based on a lecture delivered by Mr. A. C. Annis, to The Institution of Production Engineers. The methods described and illustrated apply to the manufacture of large steam turbines at the Company's Trafford Park Works: the machines considered are both single and multi-cylinder turbines of capacities ranging from 20,000 kW to upwards of 200,000 kW. Detailed description of all aspects of turbine manufacture is not given, but illustrations are used liberally to supplement the text.

Bailey, A. R. **"A Text-Book of Metallurgy."** 2nd edition. *London, Macmillan,* 1960. 561 *pages. Illustrated. Diagrams.* 30s.

The second edition of this standard work has been considerably expanded, notably in those sections dealing with crystallisation from the liquid state, plastic deformation theory, powder metallurgy and the benefaction of iron ores. The scope has been extended to include material on the metallurgy of radio-active metals and other microscopic techniques, zone refining, "FluoSolids" roasting, blast furnace production of zinc and the extraction of titanium and uranium. An appendix gives detailed guidance on the preparation of metallurgical reports. Intended for university and technical college students.

Contents:- Crystallography of pure metals — Atomic structure and cohesion between atoms — Binary alloying — Constitutional diagrams of binary alloying — Physical examination of the internal structures of metals — Metal winning: occurrence and ore preparation — Metal winning: general methods of extraction and refining — Metal winning: production of non-ferrous metals — Metal winning: iron and steel making — Metal melting, alloying and casting in practice — Mechanical working and other shaping and treating processes — Testing metals — Temperature measurements in metallurgy. *Appendices*:- Elements and their electron groups—Equilibrium diagrams of important binary alloy systems — Blast furnace production of zinc—Notes on writing metallurgical reports.

Betteridge, W. **"The Nimonic Alloys."** *London, Edward Arnold (Publishers),* 1959. 332 *pages. Diagrams.* £4 0s. 0d.

The author of this book, who is a member of the staff of the Mond Nickel Company, states in his introduction "Any attempt to present the current stage of development in a continually expanding field of knowledge is inevitably subject to the limitation that before this summary appears in print much of the information is out of date . . . Nevertheless in view of the widening interest in high temperature alloys of this (the Nimonic) type, particularly outside the gas turbine industry, and the fact that a good deal of the information has been well established for a number of years and has become generally accepted as reliable, it appears likely that a compilation of this character will be useful, both as an introduction for those to whom the alloys are new materials, and as a reference book for those who are already familiar with them . . . In the preparation of this book an endeavour had been made to satisfy the needs of the user of the alloys: the information therefore deals mainly with their metallurgical characteristics and their mechanical and physical properties, and with suitable methods of treatment and manipulation. Manufacturing and processing techniques, and the fundamental factors which are responsible for the particular characteristics of the alloys, have been discussed only briefly, when they are relevant to properties and uses."

Contents:- Requirements of high temperature alloys — The range of alloys of the Nimonic series — Constitution — Analysis and identification — Hot and cold working — Heat treatment — Physical properties — Mechanical properties at normal temperatures —Corrosion resistance — Joining — Nimonic alloys as castings — Machining and finishing — Inspection methods — Applications.

British Productivity Council, London. **"Raising Productivity in the Smaller Firm."** (Case Studies prepared by the National Union of Manufacturers' Advisory Service (Numas)). *London, British Productivity Council,* 1959. 28 *pages.* 2s. 6d.

Reports of 12 investigations undertaken by NUMAS in various industries, in which the techniques of work study, costing, and production control were used.

Croome, Honor. **"Human Problems of Innovation . . . Based on a Study of some Scottish Firms"** by Tom Burns and G. M. Stalker. *London, H.M.S.O.,* 1960 36 *pages.* (Problems of Progress in Industry — 5.) (Department of Scientific and Industrial Research.) 2s. 6d.

The firms on whose experience this study is based were mostly those taking part in the scheme originated by the Scottish Council (Development and Industry) to stimulate the growth of the electronics industry in Scotland. "The kind of management organisation and practice, including relationships between different levels of management, which will work when a business is running on an even keel using well tried methods . . . will not work where technical methods are rapidly changing". This pamphlet recounts what happened between 1953 and 1957 in certain firms which entered a new business field involving rapid technological development. The author concludes her study by saying that "the firm should . . . regard the continuous, deliberate re-casting of its own structure, the establishment of 'organic' relationships, and the maintenance of a social climate in which these can flourish, as no less important a part of the innovating process than the building of laboratories, and the recruitment of scientists and technologists."

Department of Scientific and Industrial Research — *Building Research Station.* **"Modern Multi-storey Factories: A Discussion of Their Design"** by W. A. Allen. *London, H.M.S.O.,* 1959. 17 *pages. Illustrated.* 2s. 6d.

Department of Scientific and Industrial Research. **"Automatic Control in the Soviet Union. Report of a Visit to the Soviet Union in May 1959 to Study Progress in Automatic Control Applied to Industrial Production."** *London, the Department,* 1959. 64 *pages. Diagrams.*

In 1958 the President of the Academy of Sciences of the U.S.S.R. wrote to the British Council proposing an exchange of visits by groups of specialists in the field of cybernetics, which later was interpreted as "Automatic control and its applications to industry". Six Russian engineers visited this country in 1958, and this report is an account of the return visit of six British engineers to Russia. The report includes:- (a) A list of institutions visited with the names of the directors and some other personnel, and a brief indication of their fields of work. (b) A brief statement of the teams' general conclusions on the present state of the industrial application of automatic control in the Soviet Union. (c) A note about the arrangements for the visit with some suggestions for possible improvements in the case of future visits. (d) More detailed accounts of the work seen in the various establishments. This will be found to include little information of use for furthering British developments, but will provide detail in support of the conclusions under (b) and will be useful in the case of follow-up visits by other persons.

Department of Scientific and Industrial Research. "**Scientific Research in British Universities, 1958 - 59.**" *London, H.M.S.O.,* 1959. 446 *pages.* £1 5s, 0d,

Detailed subject list of research being conducted at British universities, arranged under universities with a subject and name index.

Directory of Opportunities for Qualified Men. *London, Cornmarket Press,* 1960. 128 *pages. Diagrams.* 8s. 6d.

This is a valuable aid to the fully qualified young man or woman who wants information about firms and other organisations which are seeking personnel. It includes information on executive courses, opportunities abroad, opportunities for qualified women, and a list of organisations. This latter section gives information on the work of the organisation, its location, training facilities, salaries, pension schemes, and the types of personnel required.

Garforth, F. I. de la P. "**Management Development : A Systematic Approach to the Provision of Supervisors and Managers.**" *London, Institute of Personnel Management,* 1959. 71 *pages. Charts.*

The Acton Society Trust's report on *Management Succession* revealed that few firms in this country had coherent management development policies. This pamphlet, which is written primarily for the small and medium sized firm, but which should be useful to larger firms also, is essentially a guide to the policies and routines of personnel management with especial reference to the management of managers. It has four main sections: (1) What have we got? (Methods of appraising and recording the efficiency of staff.) (2) What do we want? (Forecasts of vacancies; job studies; job specifications); (3) How can we get it? (Recruitment policy; Talent spotting; advertising; (4) How can we best use it? (Training schemes, coaching, job rotation and exchange and other schemes); (5) Initiation and operation of systematic management development policy. In addition there is a section with pertinent quotations from management literature, and suggestions for further reading; a bibliography; and five sample charts or forms.

Hurd, Joyce. "**Adhesives Guide.**" *Chislehurst, Kent, British Scientific Instruments Research Association,* 1959. 137 *pages.* (B.S.I.R.A. Research Report, M. 39.) 20s.

This book is an attempt to provide a guide, previously lacking, to adhesives commercially available in Great Britain, and to their properties and fields of application. It includes tabulated data on about 400 individual adhesives, made by about 100 firms, and notes on about 50 main types of adhesives; brief notes on the classes of adhesives for use when joining basic types of materials; and an index of trade names. The Association does not claim that the guide is complete because some firms did not reply to requests for information; nor have the adhesives been tested in connection with the survey.
Contents: Introduction (Notes on adhesives and adhesive bonding) — Notes on choice of adhesive for various materials — Encyclopaedia of basic types of adhesive — Classification of manufacturers by basic type of adhesive made — Catalogue of adhesive manufacturers and their products — Trade names index — Miscellaneous adhesive recipes — British organisations concerned with adhesives — Bibliography.

Institute of Personnel Management, London. "**Operational Research and Industrial Management.**" Part 1 by Stafford Beer. Part 2 by R. W. Revans. *London, the Institute,* 1959. 25 *pages.* 3s. 6d.

Presented to the Institute's Annual Conference, 1959. Although the "human element" in the man-machine-materials-money systems, examined and devised by operational research methods is not usually the subject of special study, the authors claim that operational research is relevant to personnel management. It can be used to examine O.R. organisation itself; and this study might reveal points of interest for other types of organisation. The only tool available commonly for discussing organisation is the "family tree", which Mr. Beer says is inadequate and might be replaced by an operational research model, which would reveal more accurately and clearly the structure of a complex organisation. These points are discussed by Mr. Beer. Professor Revans discusses the application of operational research to personnel problems themselves, and describes an investigation conducted in Lancashire hospitals to discover the reasons for student-nurse wastage.

Jackson, A. "**Steelmaking for Steelmakers.**" *Sheffield, United Steel Companies Limited,* 1959. 265 *pages. Illustrated. Diagrams.* £2 0s. 0d.

This book is based on lectures delivered to evening students, technical societies, and to the Appleby-Frodingham Melting Shops Metallurgical Society, which were originally published in *Man and Metal,* the journal of the Iron and Steel Trades Confederation. It is directed primarily to men engaged in steel making, who wish to learn more about their work, and who can relate what they read to their daily practice. He suggests that such men should form small groups in order to read and discuss what they read under the leadership of an able technician. The book is well illustrated by photographs and diagrams.
Contents: - Refractories—Refractories in furnace operation — The "all basic" furnace — Silica roof life — Instruments and instrumentation — Instrument and automatic control — Research department to steel and back again — Fuel — Theory of combustion — Flame in the furnace — Efficient fuel utilisation aided by instruments — A modern automatic control panel — The furnace man's glasses — Description of the open-hearth furnace — Taking over a steel furnace — The Chemistry of steel making — Removal of sulphur — The boil — Deoxidation — The ingot — Dolomite and fettling — Tapholes — Works costs — Pit practice — Teeming the heat — Oxygen for steelmaking — Conclusion — Appendix. (Glossaries — Conversion factors — Measures — Analysis of some steelwork materials — Composition of refractory bricks — Gases — B.Th.U's. per cubic foot — Solid and liquid fuels — Uses and properties of refractory bricks — A simple explanation of the three different ingot structures) — Addendum. (Simple physics and chemistry. Illustrates some simple physical and chemical principles useful to steelworkers, based on part of the Appleby-Frodingham Junior Works Course for young operatives.)

Management Consultants Association, London. "**Cutting Clerical Costs.**" *London, the Association, n.d.* 7 *pages.*

A brief guide to possible opportunities of reducing clerical costs.

Ministry of Aviation. "**Second Interim Report on CO_2 Shielding of Metallic Arc Welding of Aircraft Steels and Alloys combined with the use of C.P. Welding Generators.**" Prepared by the British Welding Research Association under Ministry of Supply Contract 6/Aircraft/13832/CB6(b).

Ministry of Defence — *Joint Intelligence Bureau.* "**A Guide to Government Departments and other Libraries and Information Bureaux.**" *London, the Ministry,* 1959. 131; Mimeo. Reference only.

"DIXOL"

SOLUBLE OILS

specified by

NORTHERN ALUMINIUM CO. LTD. Banbury

The 'hot-rolling' of an aluminium-alloy ingot in a two-high reversing 84-in. Brightside mill, using clear Dixol soluble oil emulsion as a coolant and lubricant. The emulsion, in a dilution of $1\frac{1}{2}\%$, is applied by spraying on to both the rolls and the ingot.

To meet the requirements of British Standard or Ministry of Supply specifications, Northern Aluminium maintain rigid technical control throughout production. In line with this insistence on top quality, they use DIXOL OILS, as lubricants and coolants, in their Banbury Works.

This is a plant of yet another famous Company to place complete trust in Wakefield-Dick production oils. These tried and proven lubricants can help you in your plant. They are technically the most advanced in the world and for dependability and economy are unsurpassed. "Cutting and Metalworking Oils" is a booklet which shows how output efficiency can be increased while economies are being made. May we send you a complimentary copy?

The Guiding Light INDUSTRIAL WAKEFIELD-DICK LUBRICANTS ***in Lubrication***

WAKEFIELD-DICK INDUSTRIAL OILS LTD.

CASTROL HOUSE, Marylebone Road, London, N.W.1.
A member of the world-wide Wakefield Castrol Group.

The Council of the Institution

1959/1960

President

G. Ronald Pryor

Vice-President

H. Burke

Chairman of Council

H. W. Bowen, O.B.E.

Vice-Chairman of Council

R. H. S. Turner

Immediate Past Chairman of Council

H. G. Gregory

Past Presidents

Major-General K. C. Appleyard, C.B.E. Sir George Bailey, C.B.E. E. W. Hancock, O.B.E. The Rt. Hon. the Earl of Halsbury Sir Leonard Lord, K.B.E. The Rt. Hon. Viscount Nuffield, C.H., G.B.E. Sir Walter Puckey Norman Rowbotham, C.B.E. J. D. Scaife Dr. H. Schofield, C.B.E. The Rt. Hon. the Lord Sempill, A.F.C. Sir Cecil Weir, K.C.M.G., K.B.E., D.L., M.C.

Presidents of Councils outside the United Kingdom

Australian Council — J. M. Steer
South African Council — C. J. Mogford

Chairmen of Regional Committees

East & West Ridings
H. Crompton
Eastern
K. S. Jewson
Midlands
H. Tomlinson
North Midlands
A. G. Clark

Northern
F. Robinson
North Western
H. Mason
Northern Ireland
J. L. Fromson
Scotland
R. W. Mackay

South Eastern
A. L. Stuchbery
Southern
H. P. Mott
South Western
S. G. E. Nash
Wales
H. G. H. Dixon

Additional Representatives on Council

East & West Ridings
R. W. Asquith
Midlands
T. W. Elkington

North Western
J. H. Winskill
South Eastern
J. L. Gwyther

Chairmen of Standing Committees

B. E. Stokes (*Editorial*)
B. G. L. Jackman (*Research and Technical*)
F. C. Cooke (*Papers*)
L. W. Bailey (*Library*)
W. G. Ainslie (*Education*)
R. E. Mills (*Standards*)
A. Betts Brown (*Membership*)

Elected Members

G. R. Blakely C. T. Butler R. S. Clark J. V. Connolly Prof. N. A. Dudley B. H. Dyson E. Percy Edwards P. H. W. Everitt J. France B. C. Harrison E. Levesley R. N. Marland Dr. T. U. Matthew S. G. E. Nash J. Silver H. Unsworth R. J. C. Whitaker G. A. J. Witton

Chairmen of Sections outside the United Kingdom where Councils are not established

Bombay
A. Miller
Canada
S. S. Pritchard

Calcutta
T. R. Gupta
New Zealand
J. C. Fantham

Overseas Councils

AUSTRALIA

President
J. M. Steer

Chairman
E. J. W. Herbert

Immediate Past President	Vice-Chairman	Honorary Secretary	Honorary Treasurer
W. Gwinnett	H. J. Baker	L. W. Worthington	K. G. Slorach

Delegates

B. H. Coombes, C. Curtis, R. W. Deutsher, S. Downie, N. L. Eaton, N. A. Esserman, C. A. Gladman, R. Harris, A. G. Jones, A. E. Newcombe, A. Pead, F. W. Penny, C. Pullen

SOUTH AFRICA

President	1st Vice-President	2nd Vice-President
C. J. Mogford	D. A. Petrie	G. G. Tardrew

Past Presidents

A. B. Anderson, R. H. Arbuckle, L. H. L. Badham, D. N. S. Clare, W. G. Gillespie, H. J. G. Goyns, J. Henry, T. H. Hunter, D. Lion-Cachet, J. Renwick, D. E. Hamm

Elected Members

R. W. Chapple, G. T. Chawner, E. H. Dallas, P. C. Ellett, D. A. Horton, M. McKenzie Hunter, G. K. Melvill, H. H. Waters, R. Young

---

SECTION CHAIRMEN

H. J. Baker	*Adelaide*
J. Silver	*Birmingham*
A. Miller	*Bombay*
T. R. Gupta	*Calcutta*
S. S. Pritchard	*Canada*
H. G. H. Dixon	*Cardiff*
W. C. Hosken	*Cornwall*
A. S. Dick	*Coventry*
A. G. Clark	*Derby*
G. L. A. Draper	*Doncaster*
R. W. Mackay	*Dundee*
R. Grant	*Edinburgh*
G. V. Stabler	*Glasgow*
D. Stocks	*Gloucester*
R. W. Asquith	*Halifax & Huddersfield*
L. L. Bott	*Ipswich & Colchester*
R. Shilton	*Leeds*
R. M. Evans	*Leicester*
J. Cunningham, M.B.E.	*Lincoln*
H. O. Pate	*Liverpool*
G. A. J. Witton	*London*
G. Kelly	*Luton*
H. C. Knott	*Manchester*
E. J. W. Herbert	*Melbourne*
J. C. Fantham	*New Zealand*
F. Robinson	*Newcastle upon Tyne*
J. L. Fromson	*Northern Ireland*
W. A. Pitt	*Norwich*
B. A. Green	*Nottingham*
L. P. Coombes	*Oxford*
L. P. Simpson	*Peterborough*
W. L. Jones	*Preston*
H. P. Mott	*Reading*
R. Bradford	*Rochester*
H. Steel	*Sheffield*
S. L. Robinson	*Shrewsbury*
C. J. Mogford	*South Africa*
E. S. Hammett	*South Essex*
J. S. Hopkinson	*Swansea*
J. B. Turner	*Southampton*
H. A. Armstrong	*Stoke-on-Trent*
C. S. Curtis	*Sydney*
N. E. Langdale	*Tees-Side*
S. G. E. Nash	*Western*
P. J. Shipton	*Wolverhampton*
J. D. Nicholls	*Worcester*

GRADUATE SECTION CHAIRMEN

D. W. Edwards	*Birmingham Graduate*
B. Brewster	*Coventry Graduate*
D. Rose	*Leeds Graduate*
R. O. Jones	*Liverpool Graduate*
P. Trosset	*London Graduate*
R. H. Cannon	*Luton Graduate*
R. C. Yarnell	*Manchester Graduate*
E. K. Stephenson	*Melbourne Graduate*
P. G. Jenkins	*Newcastle upon Tyne Graduate*
G. E. Lawson	*Rochester Graduate*
P. W. Wells	*Sheffield Graduate*
T. G. Mossman	*Western Graduate*
	Wolverhampton Graduate

REGIONAL HONORARY SECRETARIES

East & West Ridings	J. Keightley
Eastern	A. B. Brook
Midlands	A. C. Turner
North Midlands	J. Cox
Northern	T. Young
North Western	J. P. Speakman
Northern Ireland	J. G. Easterbrook
Scotland	J. Nicolson Low
South Eastern	J. Aikman
Southern	W. F. Reid
South Western	A. Eustace
Wales	A. E. Haynes

SECTION HONORARY SECRETARIES

AUSTRALIA

Adelaide (South Australia) ...	B. H. M. Coombes, 11 Elmo Avenue, Westbourne Park, Adelaide, Australia.
Melbourne (Victoria, Australia)	A. G. Jones, 13 Laburnum Street, Middle Brighton, Victoria, Australia.
Melbourne Graduate (Victoria Australia)	E. P. H. James, 455 Stephenson Road, Mount Waverley, Melbourne, Victoria, Australia.
Sydney (New South Wales)	K. G. Slorach, 98 Church Street, Castle Hill, New South Wales, Australia.

CANADA

Canada	A. M. Hand, 18 Rintella Court, Scarborough, Ontario, Canada.

INDIA

Bombay	R. D. Mistry, "Churchgate House", 32 Veer Nariman Road, Bombay, India.
Calcutta	P. J. O'Leary, c/o Guest, Keen, Williams Ltd., 41 Chowringhee Road, Calcutta, India.

NEW ZEALAND

New Zealand	A. F. Noutch, 6 Trafalgar Road, Milford, Auckland, New Zealand.

SOUTH AFRICA

South Africa	A. Aitken, 209-211 Pharmacy House, 80 Jorissen Street, Johannesburg, P.O. Box 10837 South Africa.

UNITED KINGDOM

Birmingham	W. Silberbach, 45 Bagnell Road, Kings Heath, Birmingham, 14
Cardiff	A. E. Haynes, c/o A. B. Metal Products Ltd., Abercynon, Glamorgan.
Cornwall	F. G. Hawke, 3 Bellevue Terrace, East Hill, Tuckingmill, Camborne, Cornwall
Coventry	A. S. Hopkins, 39 Oaks Road, Kenilworth, Warwicks.
Derby	P. Warburton, 16 Vicarage Road, Chellaston, Derby.
Doncaster	G. R. Wimpenny, 16 Tickhill Square, Denaby Main, Doncaster.
Dundee	A. J. Fraser, 51 Fintry Drive, Dundee.
Edinburgh	D. A. Bowman, The Scottish Council (Dev. and Ind.), 1 Castle Street, Edinburgh.
Glasgow	W. H. Marley, North British Locomotive Co. Ltd., Springburn, Glasgow, N.1.
Gloucester	B. E. Gwynne Clarke, "Chez-Nous", Okus Road, Charlton Kings, Cheltenham.
Halifax & Huddersfield ...	C. W. Overin, 353 Whitehall Road, Westfield, Wyke, near Bradford, Yorks.
Ipswich & Colchester ...	M. D. Blake, Davey, Paxman & Co. Ltd., Standard Ironworks, Colchester, Essex.
Leeds	J. Keightley, 42 Kingsley Avenue, Adel, Leeds, 16.
Leicester & District	J. A. Stovin, 14 Queens Drive, Leicester Forest East, Leicester.
Lincoln	H. Wright, 101 Longdales Road, Lincoln.
Liverpool	H. Mason, 51 Stairhaven Road, Liverpool, 19.
London	H. R. H. Palmer, Creed & Co. Ltd., Telegraph House, Croydon, Surrey.
Luton	J. F. W. Galyer, Engineering Department, Luton & South Bedfordshire College of Further Education, Park Square, Luton, Bedfordshire.
Manchester	J. P. Speakman, 223 Douglas Road, Atherton, near Manchester.
Newcastle upon Tyne ...	L. R. Douglass, Gateshead Technical College, Durham Road, Gateshead, Co. Durham.
Northern Ireland	J. G. Easterbrook, "Hilleen", 22 Ascot Park, Knock, Belfast.
Norwich	J. I. Hilder, 2a Gorse Road, Thorpe, Norwich.
Nottingham	K. Liquorish, 28 Mona Street, Beeston, Nottingham.
Oxford	K. F. Watson, 30 Stanway Road, Headington, Oxford.
Peterborough	N. Holmes, "Arncliffe", 11 Mary Armyn Road, Orton Longueville, Peterborough.
Preston	W. H. Preston, 25 Clifton Avenue, Leyland, Lancashire.
Reading	P. J. Smallbone, "Maryfield", Darlington Road, Basingstoke, Hants.
Rochester & District ...	W. G. Clements, 11 Charing Road, Gillingham, Kent.
Sheffield	W. Edwards, c/o E. Pryor & Son Ltd., West End Works, Broom Street, Sheffield, 10.
Shrewsbury	W. M. Buchan, Llanberis, 36 Mytton Oak Road, Shrewsbury.
Southampton	J. W. Taylor, High Mead, Kane's Hill, Thornhill, Southampton.
South Essex	F. Hopkinson, "Woodley", 40 Highfield Road, Chelmsford, Essex.
Stoke-on-Trent	W. Elliott, 1 Longview Avenue, Alsager, Stoke-on-Trent.
Swansea	C. L. Clarke, 11 Alder Road, Cimla, Neath, South Wales.
Tees-Side	W. Roberts, "Rosecroft", Thirsk Road, Yarm-on-Tees, Yorkshire.
Western	A. Eustace, 19 Ferndale Road, Northville, Bristol, 7.
Wolverhampton	W. T. Vaughan, "Windsor", 24 Windermere Road, Palmers Cross, Tettenhall, Staffs.
Worcester	R. Wheeler, Old Farm House, 7 Parish Hill, Bournheath, near Bromsgrove, Worcestershire

CORRESPONDING MEMBER IN MIDDLE EAST

J. Merkine, 45 Arlozoroff Street, Ramat-Gan, Israel.

CORRESPONDING MEMBER IN RANGOON

J. T. Foster, Office of the Principal, Regional Marine Diesel Training Centre, Dalla Dockyard, Inland Water Transport Board, Phayre Street, Rangoon, Burma.

CORRESPONDING MEMBER IN WEST AFRICA

H. P. Halfter, Gold Coast Railways & Harbour Admin., P.O. Box 202, Takoradi, Ghana, West Africa.

GRADUATE SECTION HONORARY SECRETARIES

Birmingham	J. R. Brownsword, 202 Buryfield Road, Solihull, Warwickshire.
Coventry	E. R. S. Marrs, 15 Montrose Avenue, Lillington, Leamington Spa.
Leeds	B. Noble, 8 Springwell View, Birstall, near Leeds.
Liverpool	J. R. Jones, 9 Beaumaris Drive, Thingwall, Wirral.
London	B. W. Jenney, 58 Langdale Gardens, Perivale, Middlesex.
Luton	D. A. Slough, 41 Felix Avenue, Luton, Bedfordshire.
Manchester	R. Whitehead, 60 Travis Street, Hyde, Cheshire.
Newcastle upon Tyne ...	M. Dewhurst, 6 Gerrard Road, Whitley Bay, Northumberland.
Rochester & District ...	D. M. Samson, 123 York Road, Maidstone, Kent.
Sheffield	P. Brown, 21 Rowan Tree Dell, Totley, Sheffield.
Western	R. E. Everhard, 25 Boverton Road, Filton, Bristol.
Wolverhampton	I. R. Jones, "Shalimar", Clive Road, Pattingham, Wolverhampton, Staffordshire.

LOUGHBOROUGH COLLEGE STUDENT SECTION

Chairman:
A. Roberts, 32 Duncan Road, Aylestone, Leicester.

Honorary Secretary:
B. G. Cousins, College of Technology, Loughborough, Leics.

MATERIALS HANDLING GROUP

Chairman:
F. E. Rattlidge, Evered & Company Ltd., Smethwick, 40, Staffordshire.

Secretary:
I. B. King, Assistant Education and Technical Officer, 10 Chesterfield Street, London, W.1.

EDUCATION DISCUSSION GROUPS

London Centre

Chairman:
C. C. Spanswick, 24 Mill Drive, Hove, 4, Sussex.

Honorary Secretary:
D. R. C. Holmes, 35 Sandringham Drive, Ashford, Middlesex.

Midland Centre

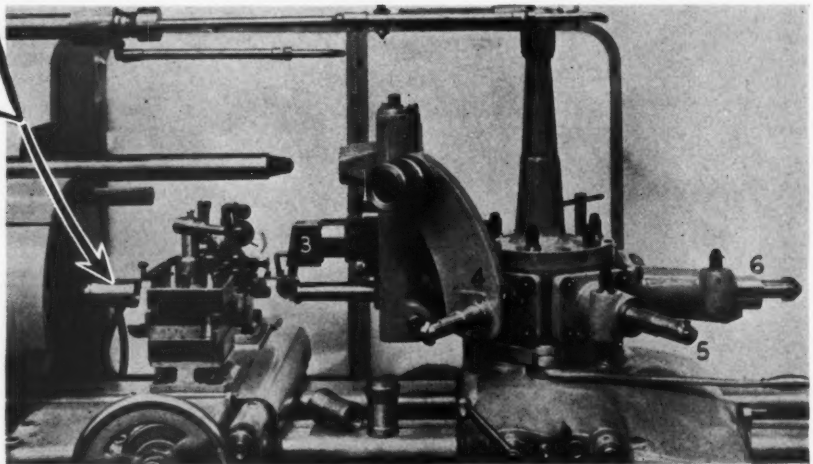
Chairman:
W. L. Jackson, Senior Lecturer in Production Engineering, Chance Technical College, Smethwick.

Honorary Secretary:
N. Ward, 88 Sutton Oak Road, Streetly, Sutton Coldfield.


Mobil Cutting Oils
SPEED PRODUCTION
Machine tool operation is daily becoming more complex . . . more difficult. Industrial speed-up and continuous production depend on cutting oils designed to fit each individual job.
Today Mobil Cutting Oils make hundreds of difficult cutting jobs possible.
These special oils are helping to increase the efficiency of machining operations everywhere.
Mobil

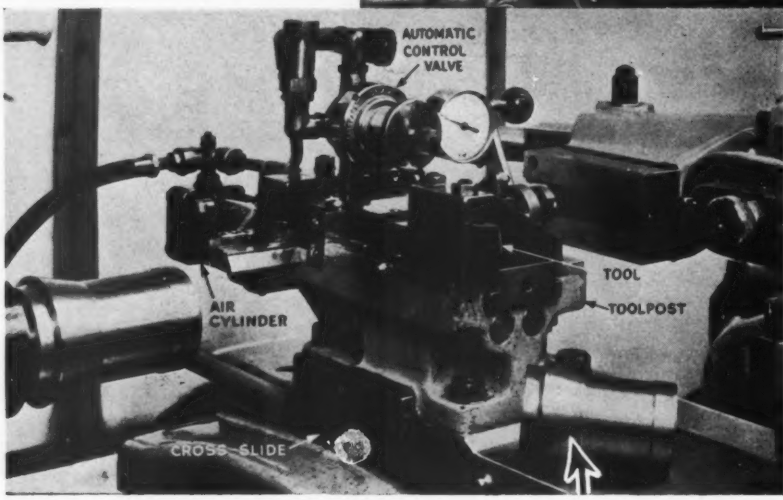
Maximum Production Special Tool Layouts

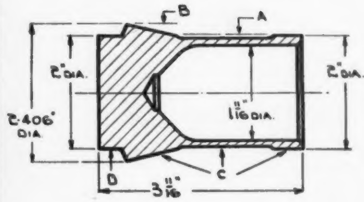
SPRING COLLET BLANKS



Ward

No. 7 PRELECTOR





$2\frac{5}{16}$in dia. ·75 Carbon Steel, En.42. Tungsten Carbide and H.S. Steel Cutting Tools

LATHE

Fitted with 12in Tudor 3-Jaw Chuck

Floor-to-Floor Time

12 mins. each.

DESCRIPTION OF OPERATION	Tool Position		Spindle Speed R.P.M.	Surface Speed Ft. per Min.	Feed Cuts per inch
	Hex. Turret	Cross-slide			
1. Feed to Stop and Start Drill	1	—	350	—	Hand
2. Support and Rough Form Taper	2	Front 1	100	66	Hand
Rough Form Head	—	Front 2	100	66	Hand
Drill and Rough Knee Turn 2" dia.	3	—	200	161	266
4. Finish Turn and Face D	—	Front 3	700	440	Hand
5. Profile Turn C (Copy Attachment)	6	Rear	700	440	186
6. Rough Bore Bottom	4	—	170	75	Hand
7. Microbore $1\frac{11}{16}$" dia.	5	—	1000	442	266
8. Finish Bore Bottom, Face and Chamfer	6	—	70	30	Hand
9. Part Off	—	Front 4	240	126	Hand

H·W·WARD & CO LTD

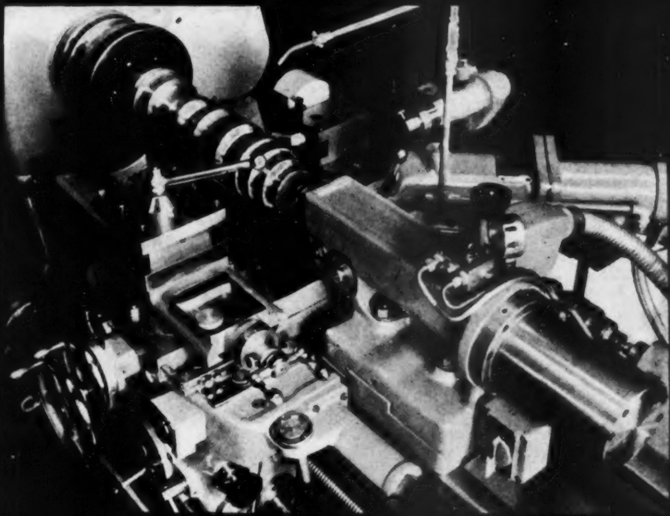
SELLY OAK BIRMINGHAM 29

TELEPHONE SELLY OAK 1131

W657

International Machine Tool Exhibition, London, 1960.
Ward Lathes will be demonstrated on Stand 205, Empire Hall, Olympia, June 25 to July 8.

LANG *Hydraulic Profiling Equipment.*

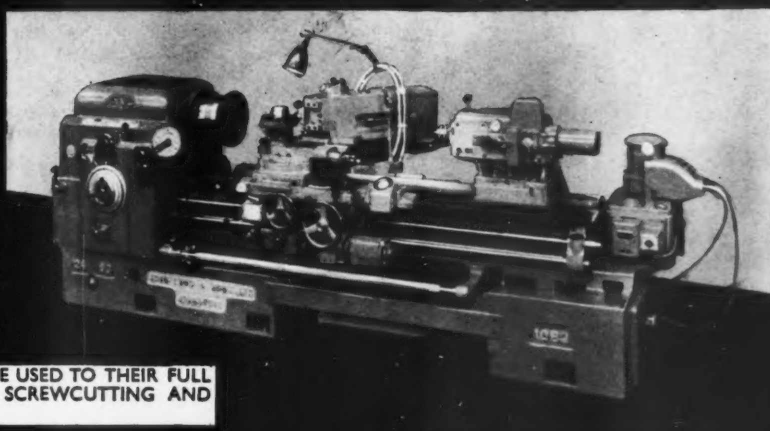


"UNITRACE" PROFILING EQUIPMENT SUITABLE FOR 16" TO 20" SWING LANG CENTRE LATHES.

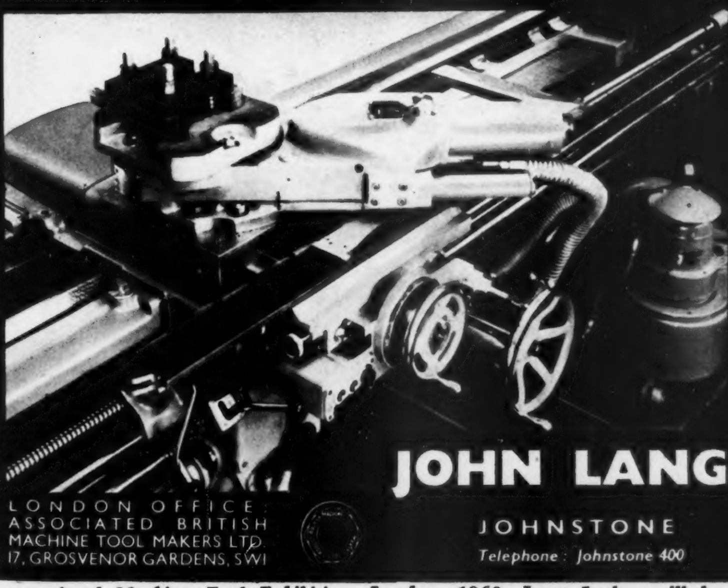
LATHE MODEL.	PROFILING CAPACITY. DIA.	PROFILING CAPACITY. LENGTH
8J6 (17")	8½"	46"
8B (16")	9½"	42", 66" or 90"
8B2 (20")	11"	42", 66" or 90"

"HYDROTRACE" PROFILING EQUIPMENT SUITABLE FOR 20" & 24" SWING LANG CENTRE LATHES.

LATHE MODEL.	PROFILING CAPACITY. DIA.	PROFILING CAPACITY. LENGTH.
10B (20")	11½"	56", 80" or 104"
10B2 . (24")	13½"	56", 80" or 104"



ALL LANG PROFILING LATHES CAN BE USED TO THEIR FULL CAPACITY ON NORMAL TURNING, SCREWCUTTING AND FACING OPERATIONS.



UNIVERSAL INTERCHANGEABLE PROFILING SLIDES SUITABLE FOR LANG 30" & 36" SWING CENTRE LATHES AND 36" & 48" SWING SURFACING AND BORING LATHES.

LATHE MODEL.	PROFILING CAPACITY. DIA.	PROFILING CAPACITY. LENGTH.
CENTRE LATHES		
12A4 (30")	30"	36" AT ONE SETTING
14A4 (36")	36"	48" AT ONE SETTING
SURFACING & BORING LATHES		
33CA4 (36")	36"	36"
42CA4 (48")	48"	48"

SUPPLIED WITH 4 BOLT TOOL SLIDE, OR QUICK CHANGE TOOL HOLDERS.

JOHN LANG & SONS LTD.

LONDON OFFICE:
ASSOCIATED BRITISH MACHINE TOOL MAKERS LTD.
17, GROSVENOR GARDENS, SW1

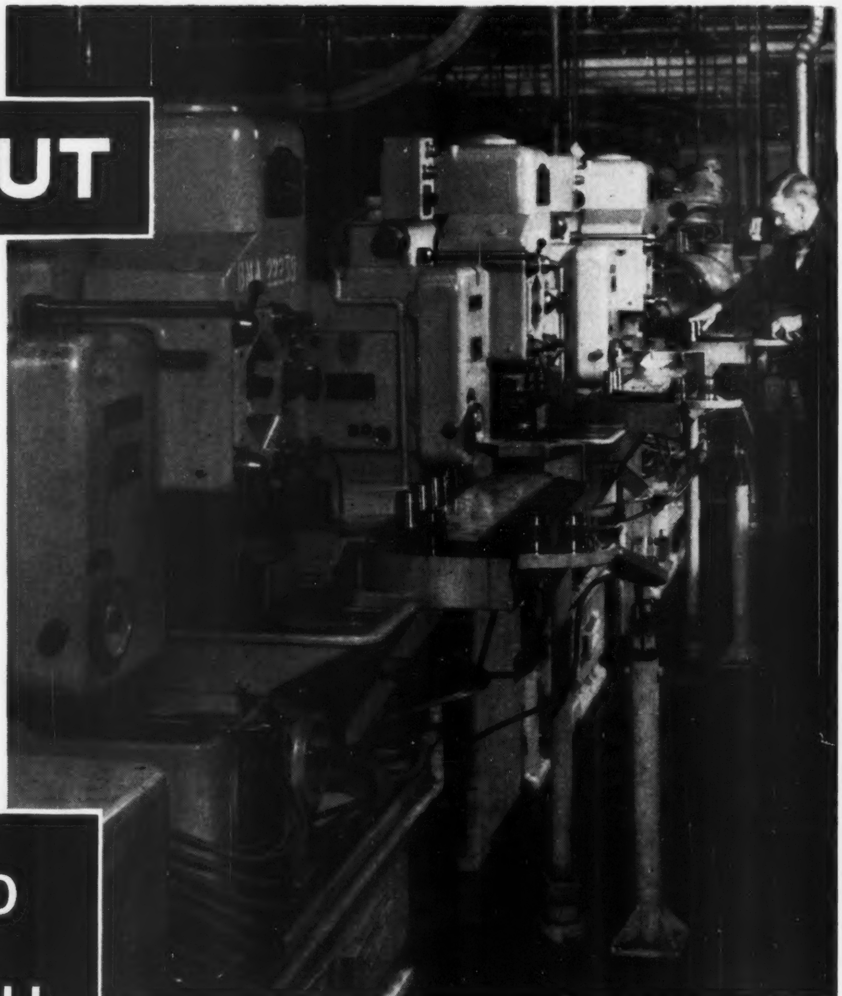
JOHNSTONE RENFREWSHIRE

Telephone: Johnstone 400 *Telegrams: "Lang Johnstone"*

International Machine Tool Exhibition, London, 1960. Lang Lathes will be demonstrated on Stand 202, Empire Hall, Olympia, June 25 to July 8.

L223E3

MAXICUT



ON STAND
43
GRAND HALL
AT
OLYMPIA
JUNE 25 – JULY 8

GEAR SHAPING MACHINES WITH AUTOMATIC LOADING

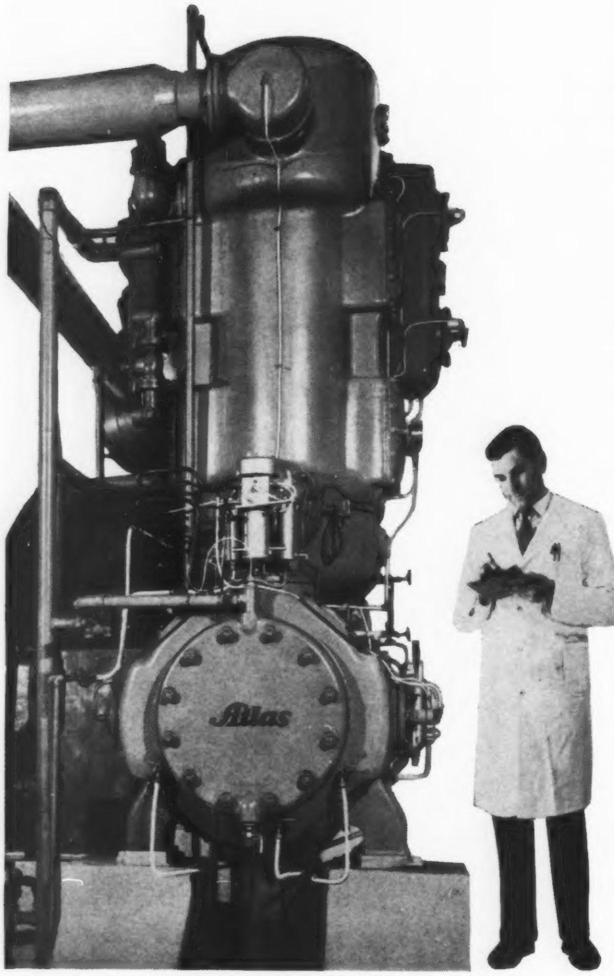
Drummond Bros. will demonstrate a Link Line at Olympia for the machining of an automobile Cluster Gear. This line will include a " Maxicut " No. 2A Gear Shaper with Automatic Loading as shown in the illustration above. Make a point of seeing this line.

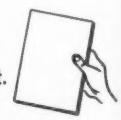
DRUMMOND BROS. LTD.
GUILDFORD · ENGLAND
Member of the Asquith Machine Tool Corporation

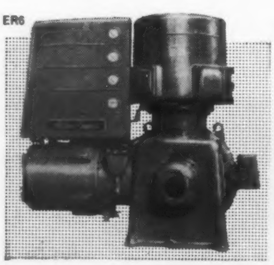
Sales and Service for the British Isles
DRUMMOND-ASQUITH LIMITED
Member of the Asquith Machine Tool Corporation

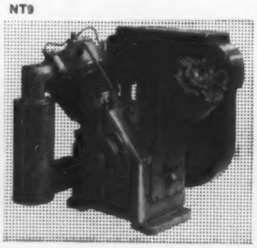
KING EDWARD HOUSE, NEW ST., BIRMINGHAM *Phone: Midland* 3431. *Also at LONDON Phone: Trafalgar 7224 & GLASGOW Phone: Central 0922*

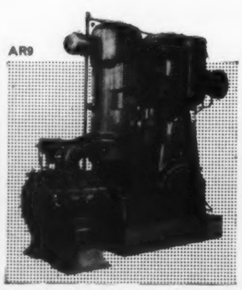
D405

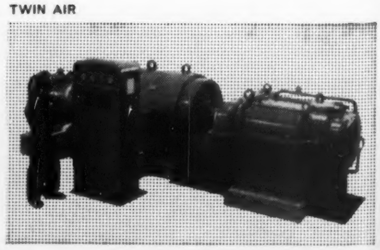












4A/ This looks good make a point of seeing it! BDD.

the most widely used turret miller in America is now being made in England by

A&S

Now large scale production in England will bring down the cost to you of the most universal of all 'universals' the Bridgeport Miller. Nearly every American machine shop has at least one. And still demand for this wonderful machine tool continues to outstrip a vastly stepped up production. Why? Because hard-headed business men realize that the Bridgeport *makes* money by coping with virtually every job likely to crop up.

- Boring
- Horizontal milling
- Vertical milling
- Drilling
- Angular milling
- Profiling
- Slotting
- Cherrying
- Fly cutting
- Hydraulic duplicating
- Right angle milling
- Boring and facing

Bridgeport

the Miller that is more universal than any 'universal'

STAND 46
GRAND HALL
OLYMPIA
JUNE 24–
JULY 8 1960

The Bridgeport Miller has been developed and perfected over twenty years. Now its renown will be further enhanced by the high reputation of Adcock & Shipley who will build it under licence for sale everywhere outside the Americas and Japan. Send for full details of the Bridgeport today.

ADCOCK & SHIPLEY LTD

P.O. Box 22, Ash Street, Leicester. Telephone: Leicester 24154-6

ONLY *Bridgeport* OFFERS SO MUCH


CINCINNATI
STAND NO
212
CINCINNATI

CINCINNATI

stand

212

INTERNATIONAL

MACHINE TOOL EXHIBITION

OLYMPIA LONDON

JUNE 25th to JULY 8th 1960

centreless grinding

MAINSPRINGS OF INDUSTRY

CINCINNATI MILLING MACHINES LIMITED,
BIRMINGHAM, ENGLAND

CINCINNATI NEDERLAND NV
VLAARDINGEN, NETHERLANDS


Greater safety for hands

W

Mos
com
oil
easi
caus
high
can
abo
S
this
cern
She
thes
sion
trou
T
to re
usec

NE

With new Shell Dromus Oils

Most modern soluble cutting oils contain phenolic compounds used as coupling agents between the oil and the emulsifier, for better blending and easier mixing. These phenolic compounds can cause skin irritation, especially where modern high-speed machines are used and the emulsion can concentrate, through the evaporation of water, above the safety level.

Shell research chemists have been working on this problem, which has been causing some concern to Management. After considerable research, Shell Dromus Oils have been reformulated and these new cutting oils now produce bland emulsions, which considerably reduce the risk of skin trouble to operators.

The real difficulty was to find a new coupling agent to replace the phenolic compounds, and Shell finally used what their chemists know as a higher fatty alcohol complex. This solved one problem, but presented another. The new coupling agent was volatile at the high temperatures normally used in blending processes. Further research found a solution to this problem by designing and installing new plant.

The new Dromus Oils are every bit as efficient as before and cost no more. They put Management in the welcome position of being able to minimise working hazards at no extra cost. And machine men need no longer be so worried about skin troubles.

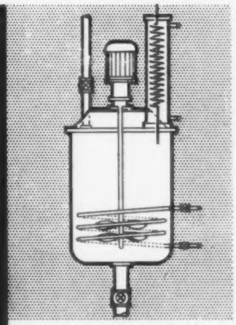
The moral of the story is that Shell research is supremely applicational. The centre at Thornton is always ready to work with even the most specialised sectors of industry to produce the right oil for the job. If you and your organisation have any major lubricating problems, it pays to get in touch with your local supplier of Shell Industrial Lubricants.

The Research Story

Shell chemists in the U.K., in Holland and in the U.S.A., prepared and examined hundreds of experimental soluble oils, and established that certain combinations of fatty alcohols could be used in place of phenolic compounds with no loss of efficiency. They set to work to discover the best combination and developed a higher fatty alcohol complex which fitted exactly. Then they realised that to blend this new coupling agent into soluble oils would require special plant and new blending techniques.

Exhaustive testing of blend stability, emulsion stability, anti-corrosion and machining properties led to selection of the most promising blends. A pilot plant was set up to produce batches of these for use in field trials.

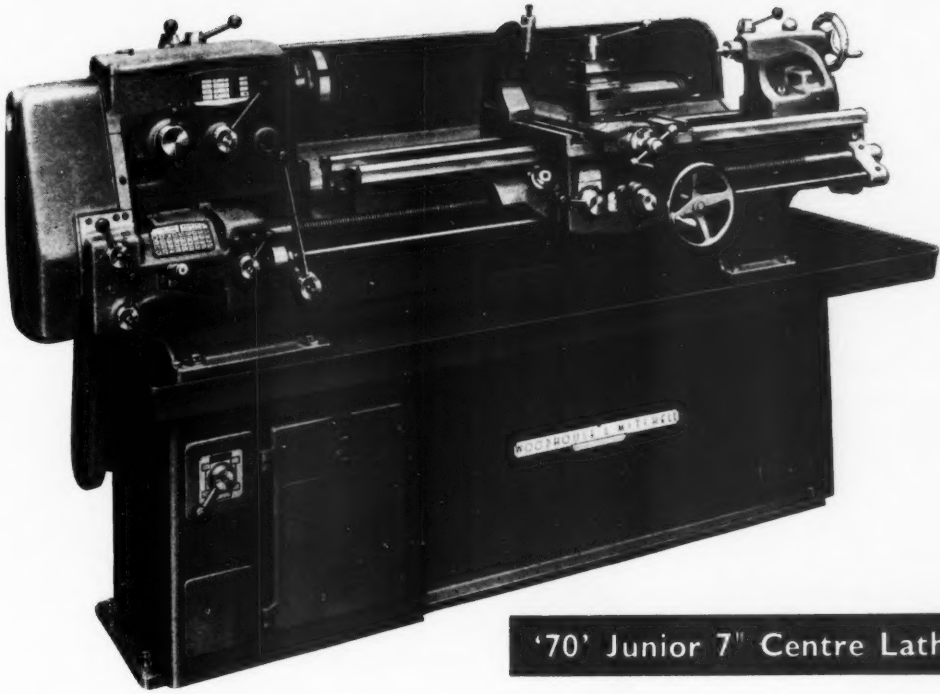
This field testing and final development proceeded for two years whilst production plants were erected at points so chosen as to give the most economical and rapid delivery throughout the United Kingdom.



This is the blending kettle. The reflux condenser beside the stirrer motor prevents the loss of constituents volatile at the blending temperature.

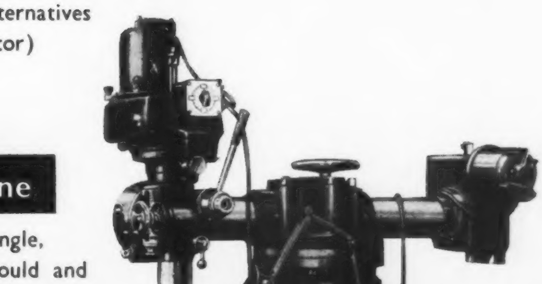
NEW SHELL DROMUS SOLUBLE CUTTING OILS

another proof of Shell leadership in lubrication



'70' Junior 7" Centre Lathe

2 h.p. motor; 8 speeds, 30-437 r.p.m. also alternatives 44-640 r.p.m. and (when fitted 2-speed motor) 30-874 r.p.m. Sizes are made to admit 45", 54" and 72" between centres.



369 Turret Milling Machine

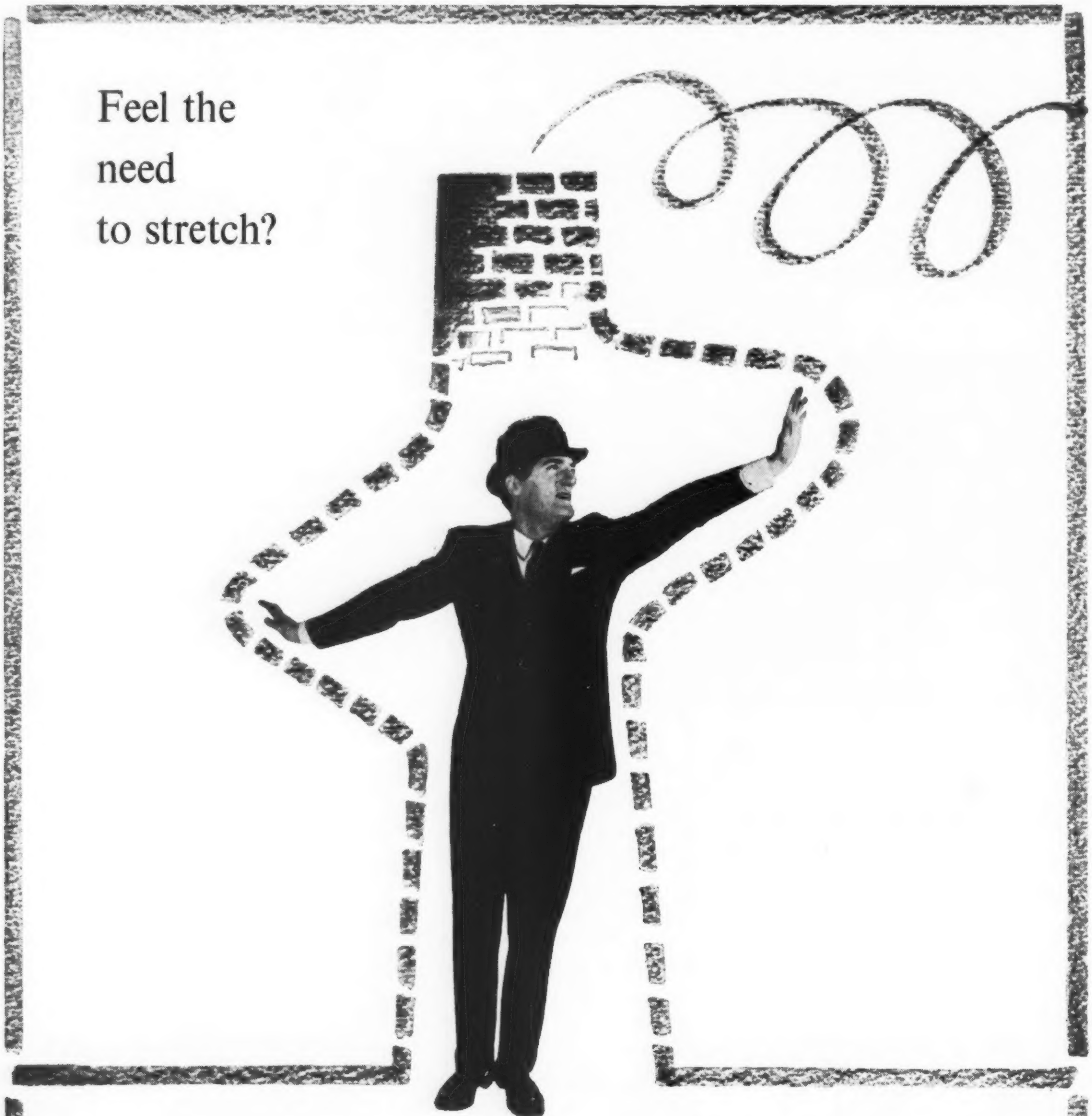
For milling, boring and jig-boring at any angle, key-way and end milling, die-sinking, mould and pattern-making Table 36" × 9", 10 spindle speeds 100-2,000 r.p.m. (alternative 200-4,000 r.p.m.).

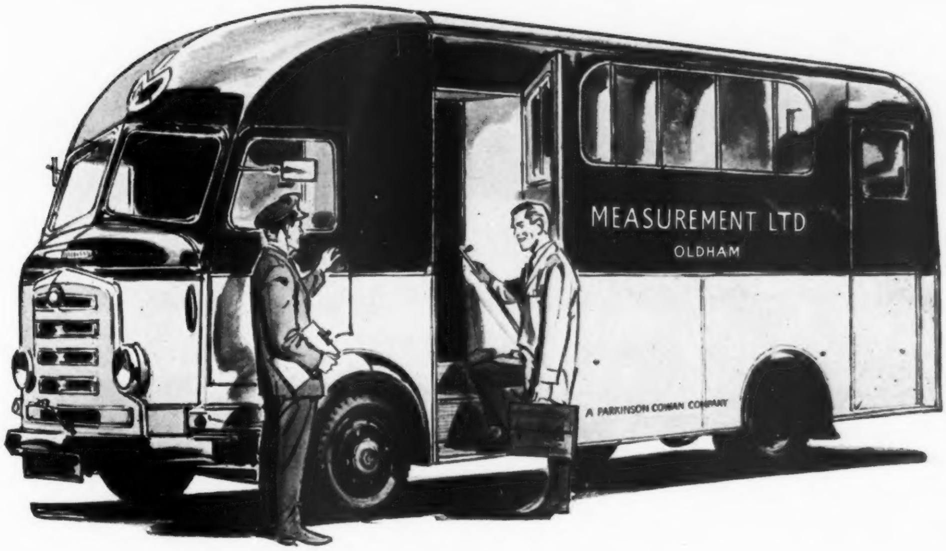
TO BE SEEN FOR THE FIRST TIME

THE NEW WM 7½" HIGH SPEED TOOLROOM LATHE

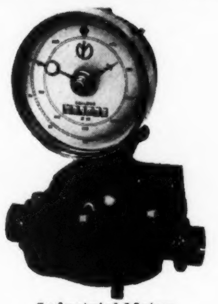
WAKEFIELD ROAD · BRIGHOUSE · YORKS

PHONE:- BRIGHOUSE 627 (3 LINES) · GRAMS:- 'WOODHOUSE BRIGHOUSE'


Feel the
need
to stretch?




Rotoplunge Pump


Industrial Meter

Stay where you are the **MEASUREMENT** *Mobile Showroom is coming to you*

If you cannot visit our showrooms, stay where you are—our new mobile showroom will come to you instead. This vehicle is fully equipped to give you a realistic demonstration of the entire range of MEASUREMENT products. You will be able to see water meters, liquid meters, liquid process control equipment and Rotoplunge pumps working under everyday conditions. Also, instruments have been specially sectionalized to give you the opportunity of thoroughly examining the high engineering standards of all MEASUREMENT products.

Our mobile showroom is staffed by trained demonstrators, who will be glad to advise on any problem connected with liquid metering, flow and process control, even if no MEASUREMENT instrument is involved.

If you would like to be informed when our mobile showroom will be next in your area, please fill in the coupon and have your secretary post it today.

meters are matters for **MEASUREMENT**

Meters for water and all liquids, liquid process control equipment, Rotoplunge pumps

MEASUREMENT LTD · P.O. BOX NO. 2 · TAMESIDE WORKS · DOBCROSS · OLDHAM · LANCS

Please advise when your Mobile Showroom will be next in our area.

NAME & TITLE

FIRM

ADDRESS

PHONE

Please tick items of particular interest

☐ WATER METERS ☐ LIQUID METERS ☐ PROCESS CONTROL EQUIPMENT ☐ ROTOPLUNGE PUMPS

A PARKINSON COWAN COMPANY

Teddington

Standard or purpose desired Pneumatic size controls can be applied to all types of Grinding Machines

* Adjustable measuring range for ·001″ to ·008″ full scale.
* Switching accuracy 0·4% of measuring range.
* Built-in facilities for timed gauging.
* Electrical circuits operate at mains voltage.
* 5 amp switch capacity—no external relays required.

PNEUMATIC SIZE CONTROLS

An example from the 'Teddington' range

For a through feed centreless grinder:—

Model 88/2 size controller with trend gauging head.

Adjustable for ½″-1½″ o.d. (or 1″-3″ o.d.) Tungsten Carbide wear surfaces.

Two control points, individually adjustable, for "Infeed" and "shut down".

TEDDINGTON INDUSTRIAL EQUIPMENT LTD.
Sunbury-on-Thames, Middlesex

Telephone: Sunbury-on-Thames 600 (9 lines)
Telegrams & Cables: Teddequip, Sunbury-on-Thames
Telex: 22742 Teddconstbry

TIE 70

CUT PRODUCTION COSTS

with the Labour-saving

Lapmaster

Here's a two-way plan that will cut to a fraction the time and expense of lapping parts in steel, monel, bronze, cast iron, quartz, plastics, etc. If your production volume warrants it, *invest* in a LAPMASTER – an automatic precision machine for the high-speed, low-cost lapping of *all* materials in *any* quantities. It will literally pay for itself many times over in a matter of months. For smaller quantities let the LAPMASTER JOB LAPPING SERVICE look after all your lapping requirements.

Whichever method you adopt you'll get greater precision, improved product performance and a *substantial reduction of your production costs.*

The popular Lapmaster 24"—for parts up to $9\frac{3}{4}$" diameter.

PROOF POSITIVE!

Why not send us a batch of parts with your own accuracy specifications? We will lap them to your requirements and return them to you quickly with accurate data on production time and a cost quotation which will certainly interest and probably surprise you.

A set of technical booklets will gladly be sent on request.

LAPMASTERS (12", 24", 36", 48", 72" and 84") are accurate to within one light band (·0000116") and produce a surface finish from 1 to 5 micro-inches or to your own requirements. They will lap from a turned face, milled face or even straight from a casting if of a precision nature.

PAYNE PRODUCTS INTERNATIONAL LIMITED

LAWRENCE ESTATE · GREEN LANE · HOUNSLOW · MIDDLESEX

Tel: HOUnslow 2205/6/7 Grams: PAYNPRO, Hounslow.

now this 'ere gear 'ere

is made from **ralsin** Nylon 11 . . . and that makes it special. If you'd made the same thing in, let's say steel for instance, it would have needed lubricating for a start all the time—which is just what you wouldn't have to do if you'd made it of RALSIN in the first place. And last; they really do last . . . made of RALSIN. Silent meshing too . . . smeshing!

*RALSIN in light engineering provides mouldings and extrusions of great mechanical strength which are dimensionally stable, shock and abrasion resistant and light in weight.

For prototype work, RALSIN can be machined. The material has a high degree of dimensional stability and piece parts produced from RALSIN are capable of being operated continuously at temperatures up to 100°C and down to as low as —64°C.

RALSIN (density 1.04) is the lightest polyamide available commercially. There are many ways in which RALSIN can improve your present products; it can also be instrumental in achieving success—particularly with intricate projects. Whiffens Publication No. M/2/16 will give you all the details you will need about its application and characteristics. Their Technical Service Department will be happy to talk over any particular details of application with you.

WHIFFENS chemicals for industry

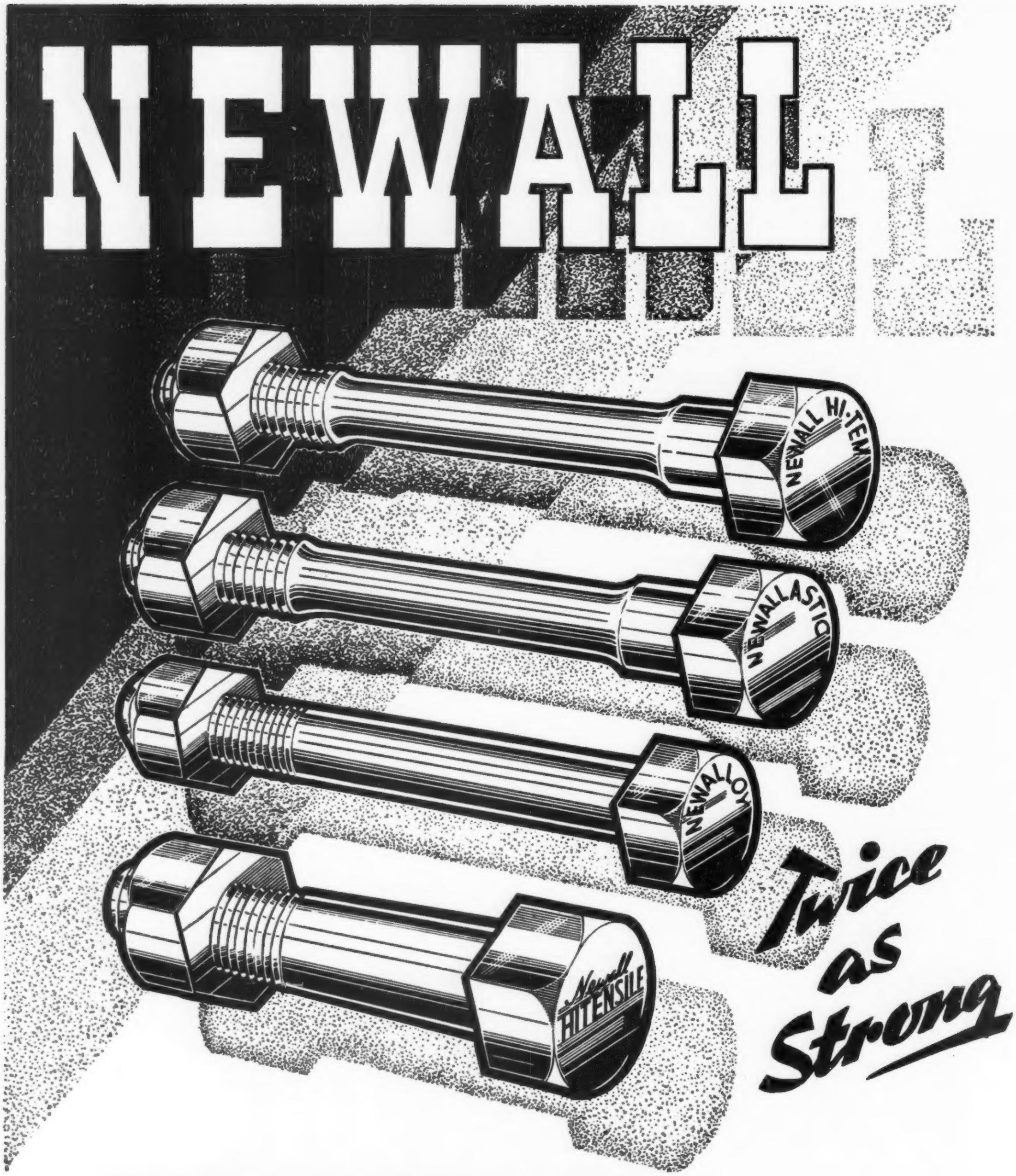
A member of the Fisons Group of Companies

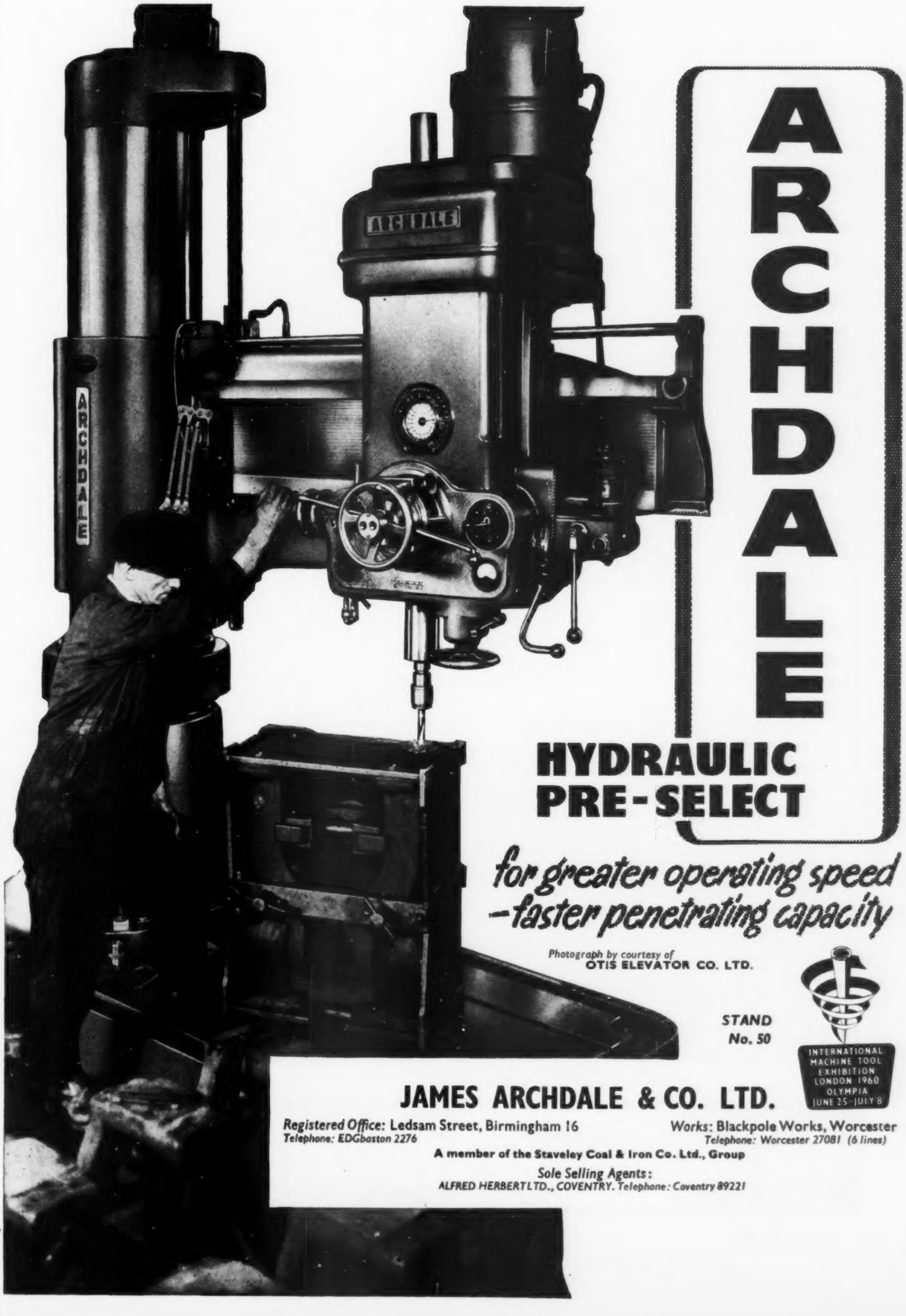
Sole agents for RALSIN in the
United Kingdom, Commonwealth of Australia and Dominions of New Zealand and Canada

WHIFFEN AND SONS LIMITED

Willows Works · Derby Road · Loughborough · Leicestershire · Telephone: Loughborough 3141

W53a


NEWALL
NEWALL HI-TEM
NEWALLASTIC
NEWALLOY
Newall HITENSILE
Twice as Strong


ARCHDALE
HYDRAULIC PRE-SELECT
for greater operating speed
-faster penetrating capacity
Photograph by courtesy of OTIS ELEVATOR CO. LTD.
STAND No. 50
INTERNATIONAL MACHINE TOOL EXHIBITION LONDON 1960 OLYMPIA JUNE 25-JULY 8
JAMES ARCHDALE & CO. LTD.
Registered Office: Ledsam Street, Birmingham 16
Telephone: EDGbaston 2276
Works: Blackpole Works, Worcester
Telephone: Worcester 27081 (6 lines)
A member of the Staveley Coal & Iron Co. Ltd., Group
Sole Selling Agents:
ALFRED HERBERT LTD., COVENTRY. Telephone: Coventry 89221

THE SOUND APPROACH TO QUIET!

. . . install clean, streamlined N.S.E. Partitioning, establish a happy congenial atmosphere and increase staff efficiency.

EASY TO ERECT
ADAPTABLE
ECONOMICAL

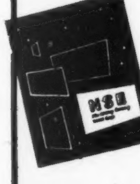
FOR OFFICE AND FACTORY

...it must be

NSE

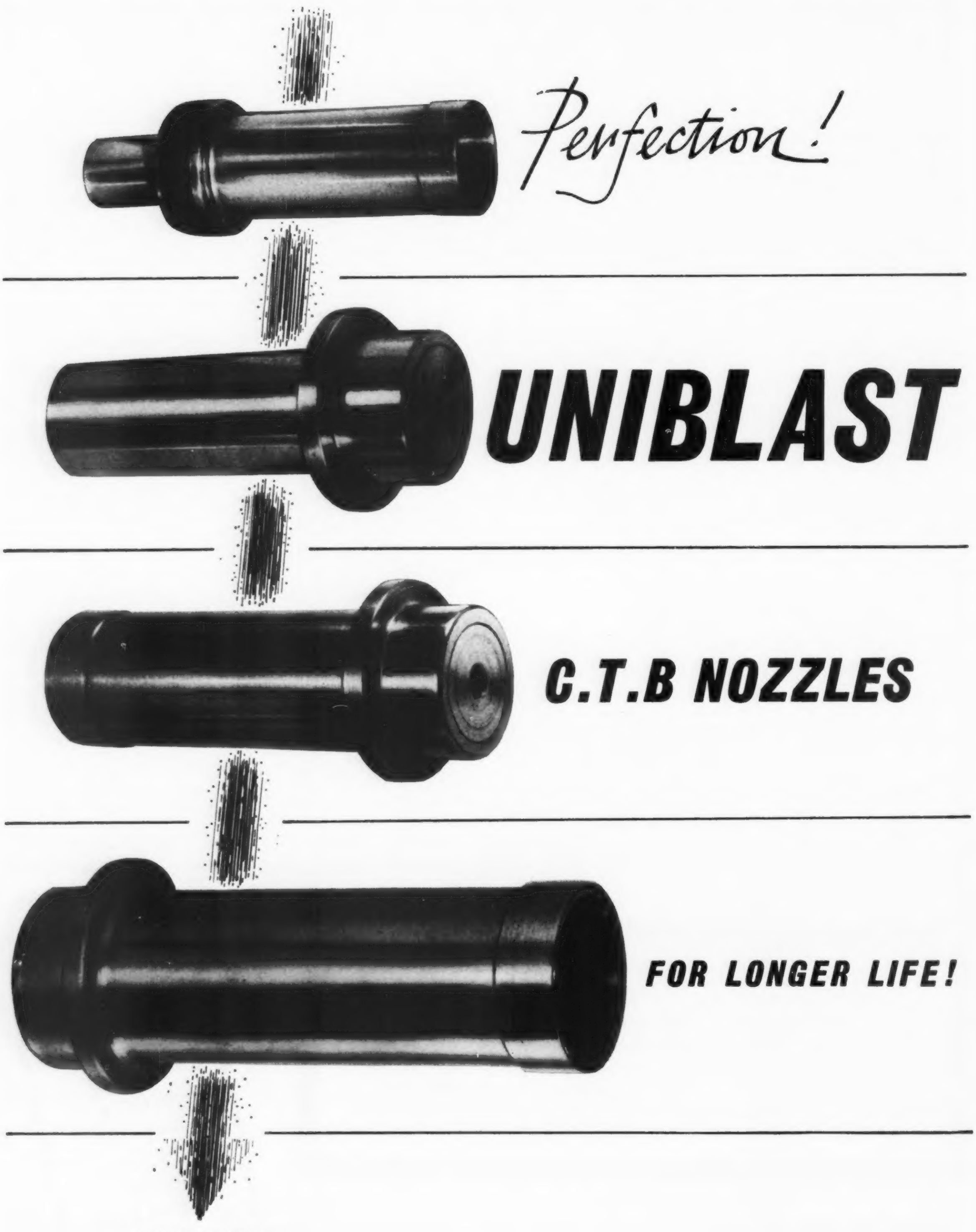
STEEL PARTITIONING

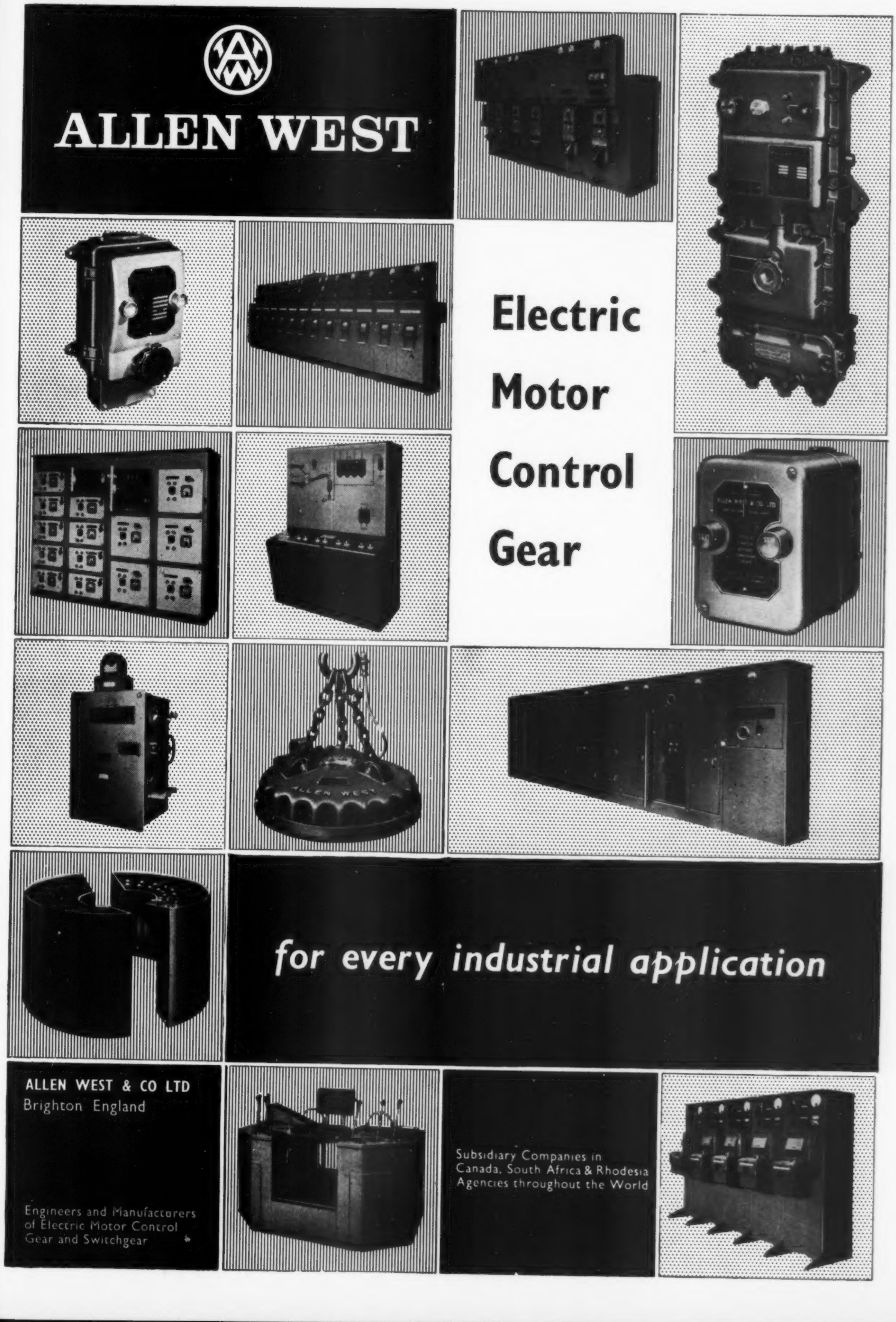
Inspect the full range of N.S.E. Partitioning and Office Equipment at our modern Showrooms in **BRISTOL, BIRMINGHAM, MANCHESTER** *or visit our London Display Centre* **149 BOROUGH HIGH STREET, S.E.1**



Send TO-DAY for our NEW FREE fully illustrated 36 page catalogue

NORWOOD STEEL EQUIPMENT LTD., HARLOW, ESSEX. TEL: HARLOW 25651



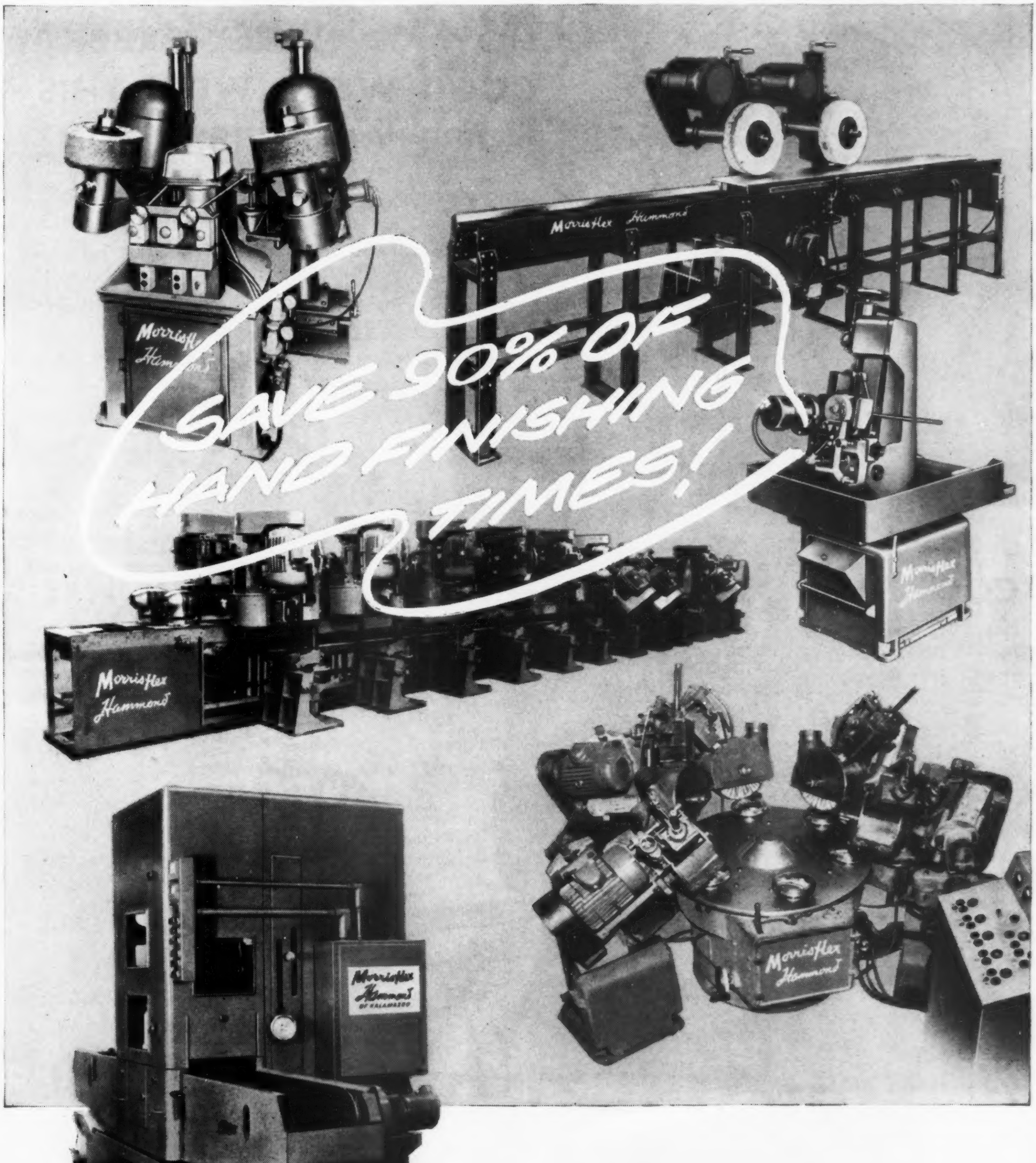

ALLEN WEST
Electric
Motor
Control
Gear
for every industrial application
ALLEN WEST & CO LTD
Brighton England
Engineers and Manufacturers of Electric Motor Control Gear and Switchgear
Subsidiary Companies in Canada, South Africa & Rhodesia
Agencies throughout the World


Air Pressure
plus
Toggle Action
Combined
in the latest
Speetog REGD. TRADE MARK
AIR OPERATED CLAMP
...equipped with efficient
'Airtog' REGD. TRADE MARK
CUSHIONED CYLINDER
The mechanical advantages of the well-known "Speetog" Toggle Action now combined with the speed and efficiency of compressed air, allows for high speed operation with secure and finely controlled clamping pressures. Any number of these Clamps can be operated instantly at the touch of a switch.
Tracing Templates are available for the use of Drawing Offices.
(Patent Pending)
MADE IN TWO MODELS
Speed Tools Ltd
VEREKER HOUSE. GRESSE ST., LONDON W.1 Museum 1039/1099.

NRP9073


Metal sawing problems?
Cold sawing machines are our speciality whether for ferrous, non-ferrous or difficult metals and we have an extensive range of standard machines which cut quickly - and accurately.
We also build machines for special applications.
If you have a cold sawing problem our experience could probably provide the solution. May we help you?
METAL SAWING & SAW SHARPENING MACHINES
RUSSELL
S. RUSSELL & SONS LTD. Bath Lane, Leicester
Backed by 45 years of specialised experience

WIN THE BATTLE OF THE BURR . .



. . BY USING **Morrisflex** *Hammond*

BUILT UNDER LICENCE FROM
HAMMOND MACHINERY BUILDERS INC. U.S.A.

B. O. MORRIS LTD. • BRITON ROAD • COVENTRY
Telephone: 53333 (PBX)
Telegrams: MORISFLEX, COVENTRY.

For magnified output . . .

use mechanical tubing . . .

Much time, labour and material is saved when mechanical steel tubing is used when making ring shaped parts such as collars, spindles, sleeves and rollers.

We carry large stocks of mild and stainless steel tube in many sizes up to large diameters and wall thicknesses. Send for booklet that gives sizes and specifications.

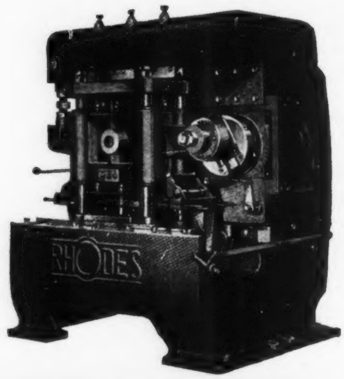
IMMEDIATE DELIVERY IN MOST CASES

Markland Scowcroft LIMITED

BROMLEY CROSS, Near BOLTON
'Phone EAGLEY 600

M119

We offer you time gained— —Not gimmicks . . .



The beauty of this machine is that exceptional speeds are combined with quick changeovers.
It is certainly the fastest press in the world. 1,000 strokes per minute if you wish, but it is an economical proposition for relatively short runs.
Here it has a great advantage over single-purpose machines.
What is more, accuracy is truly remarkable—without the aid of pilot pins.
There are no feed rolls and tool 'life' is prolonged.
It is an original design patented by Rhodes.
This press crosses the Atlantic Ocean from *east* to *west*.
All the gimmicks in the world can't add up to the know-how we've accumulated and progressively applied since metalworking first started. We've been at it for 136 years.

RHODES
ULTRA-SPEED PRESSES

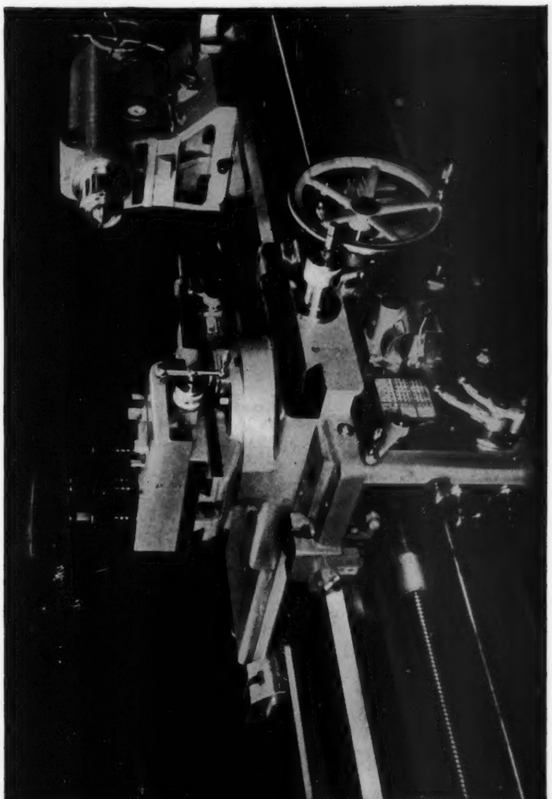
1,000 strokes per min. Makes the roll-feed dieing press obsolete.

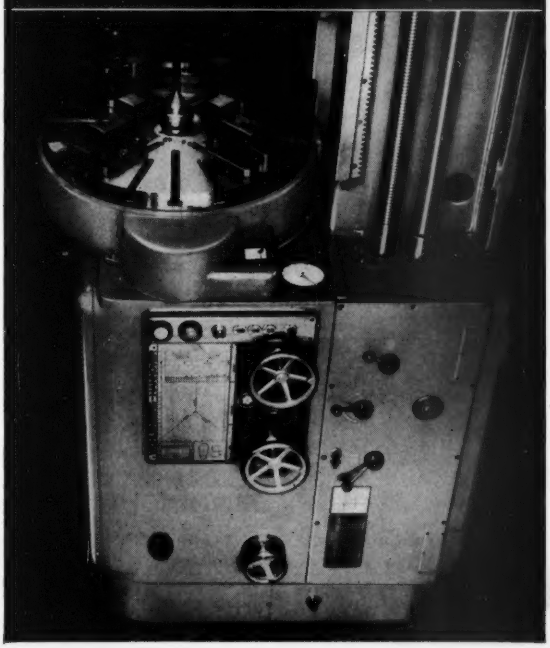
BUILT TO THE **RHODES** STANDARD

RHODES OF WAKEFIELD

JOSEPH RHODES AND SONS LIMITED
BELLE VUE · WAKEFIELD · TELEPHONE 2756 (3 lines)

HRP 2923

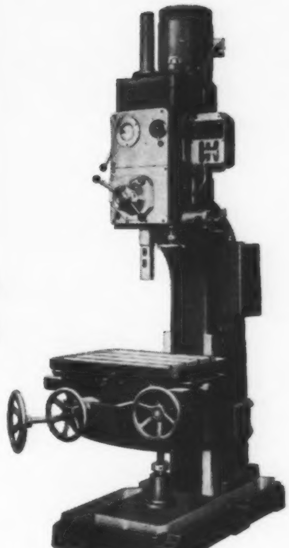




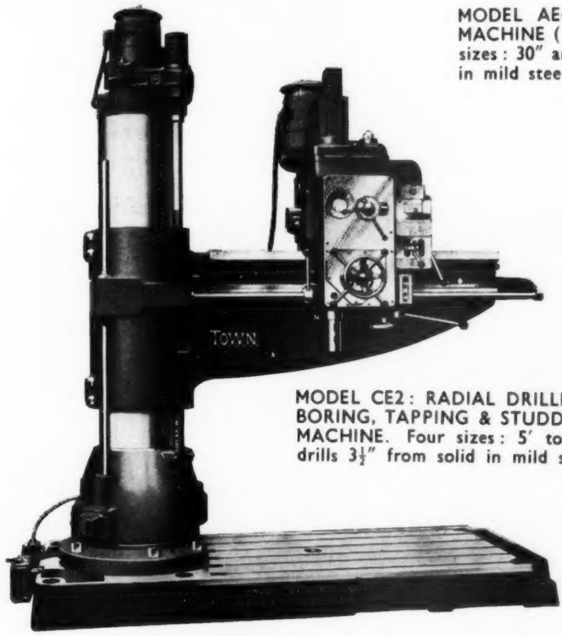
GO TO TOWN on Stand No. 57

(GRAND HALL)

at the INTERNATIONAL MACHINE TOOL EXHIBITION OLYMPIA - LONDON - 25th JUNE - 8th JULY, 1960

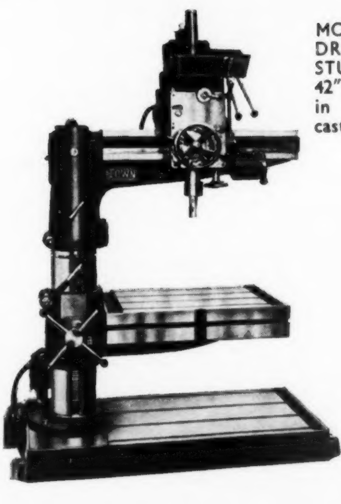


MODEL AE4: VERTICAL DRILLING MACHINE (Medium duty model). Two sizes: 30" and 36"; drills 3" from solid in mild steel.



MODEL CE2: RADIAL DRILLING, BORING, TAPPING & STUDDING MACHINE. Four sizes: 5′ to 8′; drills 3½" from solid in mild steel.

MODEL AE4: RADIAL DRILLING, BORING, TAPPING & STUDDING MACHINE. Seven sizes: 3′ 6" to 8′; drills 3" from solid in mild steel.



MODEL AE5: RADIAL DRILLING, TAPPING & STUDDING MACHINE. 42"; drills 1¼" from solid in mild steel or 1½" in cast iron.

TO BE SEEN FOR THE FIRST TIME

THE NEW MODEL CE3 4′ RADIAL DRILLING MACHINE

THE NEW 5′ PORTABLE UNIVERSAL RADIAL DRILLING MACHINE

and also Model AE6 3′ 6" Sensitive Radial Drilling Machine

FRED^K. TOWN & SONS LTD

ESTABLISHED · 1903

HALIFAX · YORKS

PHONE: HALIFAX 60373/4

"BROOMWADE" HYDRO-PNEUMATIC SQUEEZE RIVETERS have been the means of overcoming numerous riveting and punching problems which previously were considered almost impossible. Perfect rivet formation can be attained in the most restricted places, and enormous power can be concentrated in a small hand-held tool.

"BROOMWADE" Type HPS15 Squeeze Riveter. Riveting over a Nylon bearing bush to a ball selector peg during the assembly of the Standard 6 cwt. Van Gearbox.

"BROOMWADE" Type HPS5 Squeeze Riveter with push button control in use during the assembly of the inner rear hub and outer bearings to the axle shaft of the Triumph Herald.

An intensifier having a large compressed air operated piston exerts its total load on a small hydraulic ram mounted in tandem. The resultant hydraulic pressure is from 30 to 60 times greater than the air pressure used, and is transmitted to a small operating cylinder on the riveting yoke. This operating cylinder can be applied to any type of yoke, hand held, bench mounted, or floor mounted. Control of the unit can be either by foot pedal operated valve, or by remote push button.

A world-wide service organisation is available and expert advice from works-trained technical representatives.

Write for full details.

"BROOMWADE" Type HPS9 Bench - mounted Squeeze Riveter pressing in a Silent bearing to the gearbox operating shaft of the Triumph Herald.

"BROOMWADE"

AIR COMPRESSORS & PNEUMATIC TOOLS

YOUR BEST INVESTMENT

BROOM & WADE LTD., P.O. BOX No. 7, HIGH WYCOMBE, BUCKS. *Tel: High Wycombe 1630 (10 lines) Telex: 15 — 527.*

761 SAS

they are all going

to

stand No. 412

to see the

CLARE SYSTEM of milling equipment

which demonstrates improved and more efficient methods of milling. One CLARE chuck only is needed for endmills, slot drills, Woodruff and tee slot cutters, Shell/Facemills, large facemills with standardised drives, jobber chucks and drills, taper shank drills, carbide and 'Stillilt' facemills and special cutters and arbors; all without removing the chuck from the spindle.

Make a point of calling on STAND 412 — we shall be pleased to see you.

CUT BETTER WITH Clare

CLARE COLLETS LTD.

WRIGHT STREET, BROADHEATH, CHESHIRE

Telephone: **Altrincham 3701/2.** Grams: **Clarchucks, Altrincham**

INDEX TO ADVERTISEMENTS

Please note that all advertisement pages are prefixed with the letter "A"

All communications regarding advertisements should be addressed to the Advertising Managers, T. G. Scott & Son, Ltd., 1 Clement's Inn, London, W.C.2. Telephone: HOLborn 4743.
Printed by Maxwell, Love & Co. Ltd., 309 - 317 Borough High Street, London, S.E.1.